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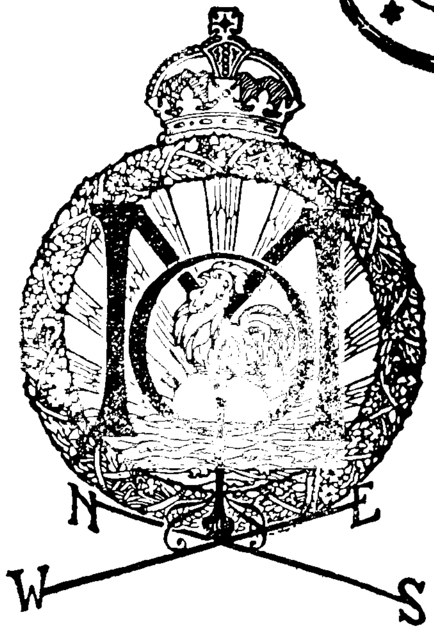

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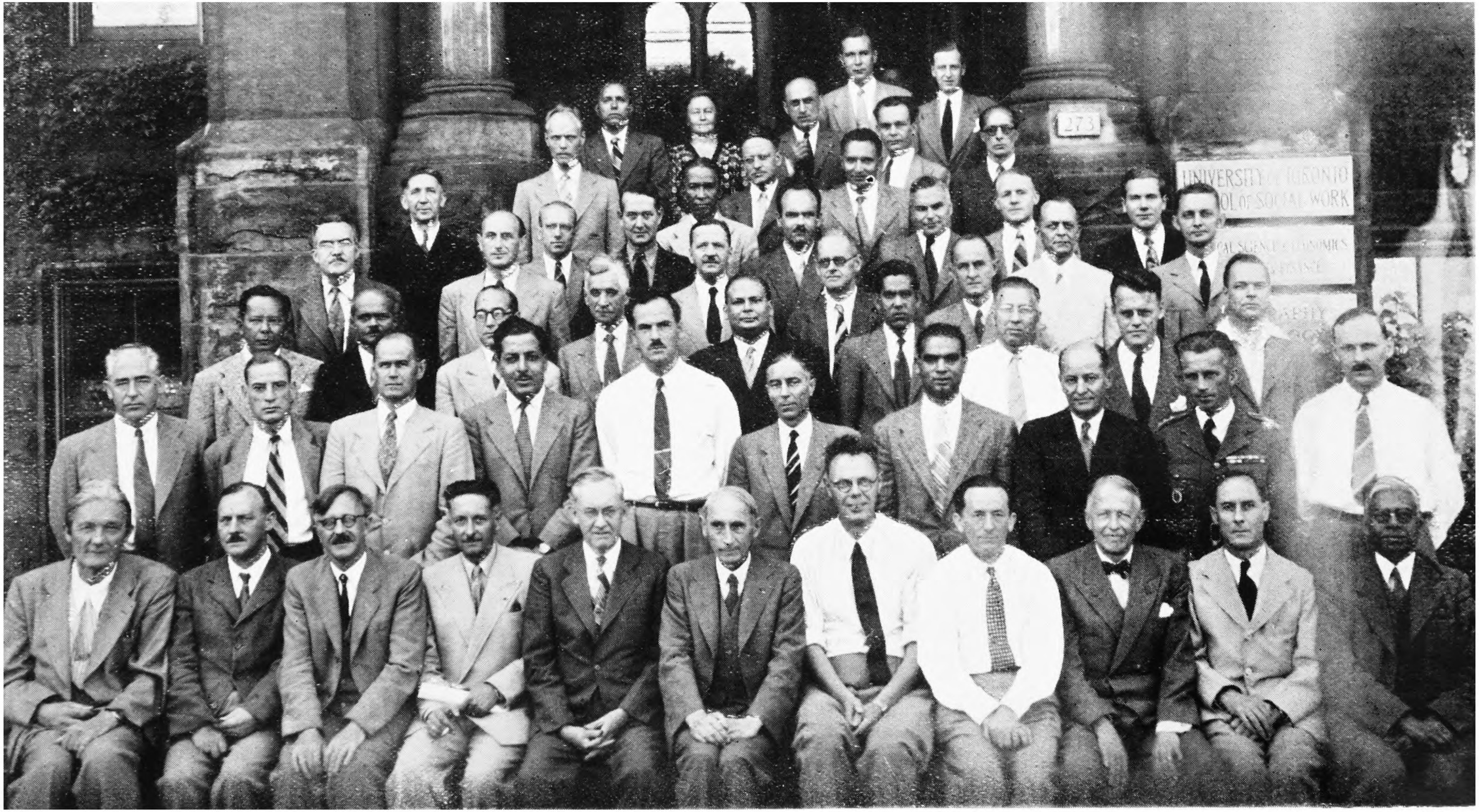
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THE MEETINGS OF THE INTERNATIONAL METEOROLOGICAL ORGANIZATION IN TORONTO AND WASHINGTON

AUGUST, SEPTEMBER, OCTOBER 1947

The meetings of the International Meteorological Organization (I.M.O.) which were held in Toronto and Washington from the beginning of August to mid October 1947, were of unusual interest, not only on account of the results achieved but also because of some of the precedents that were created. It was the first time in its 75-year history that any of the constituent bodies of the I.M.O. had met in the New World, and it was also the first occasion that all ten of the Technical Commissions had met together at the same time.

During the war the activities of the Organization were seriously curtailed, but as soon as possible after the return of peace steps were taken to set its machinery in motion once again. An extraordinary Conference of Directors was held in London in February 1946, during which new members of the International Meteorological Committee were elected and the Technical and Regional Commissions reconstituted. This Conference thus cleared the way for a resumption of the international procedures in operation before the war and for the world-wide introduction of improvements in the field of scientific meteorology made by certain countries during the war.

The objects of the meetings at Toronto and Washington were therefore to review and consolidate the progress made since the London Conference, to make plans for the future and to consider the structure of the I.M.O. and its relation to other international associations.

The meetings of the ten technical commissions were held in Toronto during August and the first two weeks of September, and were attended by 179 delegates from 44 countries. The meetings took place in the buildings of the University. The Conference of Directors under the chairmanship of Sir Nelson Johnson, President of the International Meteorological Organization, opened in Washington on September 22 and terminated in mid October.

It is the function of the Technical Commissions to consider their respective subjects and to make recommendations on them for consideration by the Conference of Directors. On this occasion over 400 resolutions were submitted by the Technical Commissions to the Conference of Directors. It is, therefore, logical to consider first the work of the commissions by giving a summary of the activities of each one written by the United Kingdom delegates attending its meetings.

Aeronautical Commission (President, Mr. A. H. Nagle, Eire; United Kingdom delegate, Mr. J. Durward).—This Commission, whose meetings extended over three weeks, prepared, as its most important task, a common text for the International Civil Aviation Organization (I.C.A.O.) and I.M.O. regulations for the provision of meteorological facilities to international aviation. Taking as a basis the " Recommendations for Standards, Practices and Procedures " produced by the Meteorological Division of I.C.A.O. the Commission agreed the changes which would be necessary to make the text of that document suitable for the I.M.O. publication " Règlement général pour la protection météorologique de l'aéronautique ". The text so amended was submitted to the Conference of Directors of the I.M.O. and to the Council of I.C.A.O. for approval.

There was a very detailed discussion on the question of codes for use in the transmission of terminal and route forecasts to ground stations and aircraft and of weather reports to and from aircraft. The agreed codes were later confirmed by the Commission for Synoptic Weather Information of the I.M.O. and by the Meteorological Division of I.C.A.O. at a special meeting held in Montreal on September 17.

Other matters upon which resolutions were prepared by the Commission were climatological statistics for aeronautical purposes, the qualifications necessary to be held by the meteorological staff engaged in providing the weather service for aviation, the exchange of publications on " pressure-pattern flying ", and methods of constructing upper-level charts.

Commission for Maritime Meteorology (President, Cdr. C. E. N. Frankcom, R.N.R.; Other United Kingdom delegates, Inst. Capt. J. Fleming, R.N., Inst. Cdr. Suthons, R.N., Secretary).—In considering the first visit of this Commission to the American continent it is of interest to note that it was an officer of the U.S. Navy, M. F. Maury, who was instrumental in convening in 1854 the first international meteorological conference and who was responsible for the commencement of organised meteorological work at sea.

Probably the most important work of the Commission was the creation of a world-wide scheme for improving the network of meteorological reports from ships in every ocean. For these reports meteorologists are largely dependent upon the goodwill of voluntary observers in the merchant ships of all nations. One difficulty in connexion with this problem is that, if all the ships of the world sent in messages at each international hour (0000, 0600, 1200 and 1800 G.M.T.) there would still be large gaps in the marine network because ships tend to keep to fixed tracks. There are also serious communication problems to be considered as many ships have limited radio facilities. A number of resolutions were passed whereby maritime countries are encouraged to recruit ships to send in reports, and the oceans have been divided into agreed areas from which ships make their weather messages to selected meteorological centres. In return for these weather messages it is the duty of the Meteorological Service concerned to issue adequate weather information to the shipping in that area.

Further resolutions on this problem proposed the establishment of meteorological liaison officers to keep contact with merchant shipping in the major ports of the world. To reduce the gaps in the marine network, the Commission recommended the establishment of automatic weather stations on islands and the detection of distant storms by radio means, by microseismic observations and by aircraft reconnaissance. A scheme to provide for the co-operation of whaling vessels in the Antarctic was also put forward.

In co-operation with other Commissions, the Commission made recommendations on methods of obtaining improved accuracy in reports from the sea, and also drew up proposals for an international meteorological publication for the use of seamen. As a result of research carried out during the war by U.S. and British naval experts, considerable interest has been displayed in wave measurement at sea and a new technique has been evolved. The Commission has recommended that, in future, ships shall be requested to report the direction, period and height of waves at sea. It is considered that the reports thus received will not only enable forecasts to be made of wave conditions in distant areas but will be of considerable scientific value. In many parts of the world (e.g. the exposed shores of Portugal, Morocco and the Azores) wave forecasts are of considerable commercial importance. A knowledge of waves is also vital for aircraft operation and is of interest to ship designers. The Commission drew up a simple code for reporting ice at sea and set up a special Committee of experts to revise the present international ice nomenclature, which is somewhat out of date. Recommendations were also made concerning the treatment of marine climatological data.

Commission for Synoptic Weather Information (President, Mr. E. Gold; other United Kingdom delegates, Mr. E. G. Bilham, Inst. Capt. J. Fleming, R.N.).—The Toronto meeting of the Commission for Synoptic Weather Information (C.S.W.I.) was a momentous one in many ways. To appreciate its special character it is necessary to recapitulate briefly the events of the previous two years.

At the beginning of the war the Copenhagen (1929) code for the international exchange of weather reports was in universal use, and it fulfilled the requirements then existing. During the war, however, the growing needs for increased precision led the allied nations to agree upon certain modifications and additions. In particular it was found necessary to use two code figures instead of one for visibility and height of cloud. Extensive changes were also made in the codes for reporting upper winds, temperatures and humidities, and in addition, entirely new codes were introduced for the exchange of analyses, reports from aircraft, sferic reports and reports to aircraft in flight. The code situation at the end of the war was therefore exceedingly complex. At the Extraordinary Conference of Directors held in London in February–March 1946, the I.M.O. provisionally approved a number of the war-time codes, and decided that the C.S.W.I. should meet at an early date to consider the many urgent problems awaiting solution. The C.S.W.I. accordingly met in Paris, in June 1946, faced with the immense task of re-examining practically all the existing weather codes and specifications and recommending new codes for universal adoption; the report of the Paris meeting (I.M.O. Publ. No. 54) runs to nearly 500 closely printed pages. Most of the 56 resolutions were approved at a meeting of the International Meteorological Committee held immediately afterwards.

It was reasonable to suppose that this meeting would have resolved most of the difficulties, but the new Paris codes did not, unfortunately, meet with unqualified approval, and it became evident that discussions would have to be re-opened at the Toronto meeting, which had been planned for August–September 1947.

The meeting was held in the Economics Building of the University from August 25 to September 13. The discussions were long and arduous, but it is gratifying to record that unanimous agreement was finally reached on the question of a universal code for surface reports, the main subject of contention. The new code retains the more important features agreed at Paris (two figures for visibility, cloud height and wind speed) while at the same time meeting the wishes of those services which do not require reports of barometric tendency in an obligatory group.

Other important changes agreed at Toronto were a new world-wide system of five-figure index numbers of stations, the specification of cloud amount by eighths instead of by tenths, and the specification of surface wind direction by units of ten degrees (scale 01–36) instead of by points (scale 01–32). In a short note it is impossible to list all the subjects discussed, but reference may be made to papers on the synoptic applications of upper air data and sferic observations by Dr. R. C. Sutcliffe and Mr. C. K. M. Douglas respectively, which provided pleasant scientific relief from the discussion on codes and specifications.

Commission for Instruments and Methods of Observation (President, Dr. J. Patterson, Canada; United Kingdom delegate, Dr. F. J. Scrase).—C.I.M.O., to give it its abbreviated name, is a new Commission instituted by the Conference of Directors of the International Meteorological Organization which was held in London in 1946. The first meeting of the Commission took place in Toronto on August 4 to 16, 1947, under the presidency of Dr. J. Patterson, formerly Controller of the Canadian Meteorological Service. As the Commission was starting from scratch the President had drawn up a formidable agenda of some 120 items and sub-items with a view to surveying the whole field of meteorological instruments and methods. Eight temporary sub-commissions were formed to consider different sections of the field and to discuss the more important items in detail.

The discussions on the various instruments and methods usually turned on questions of standardization. The general feeling about this was that, although a considerable degree of standardization of meteorological instruments is desirable, to attempt to standardise the design of relatively new equipment, such as radio-sondes, would tend to discourage further development. It was, however, agreed that intercomparison of different types is necessary, and to facilitate this in the case of radio-sondes a recommendation was made for the development of a simple reference instrument, preferably employing the Olland principle, which would not need elaborate ground equipment and which could therefore be readily used as a standard for comparison by any country.

In barometry it was suggested that a conventional standard of gravity, not subject to revision, should be used and that uniformity of practice between meteorologists and physicists should be the prime consideration in adopting a standard value. A number of recommendations were made on the design of fixed cistern barometers and on the method of reduction of pressure to standard levels. Problems of visibility measurement were considered and some changes in international practice were recommended. The Commission was of the opinion that the estimation of visibility in the day-time at land stations is better done by the simple visual method than by means of a visibility meter. Other items discussed included the standardization of thermometers and of psychrometric methods. The special needs of aviation both in regard to the measurement of wind and gustiness and to the measurement of cloud height were considered.

It was hardly to be expected that the Commission would, at its first meeting, be able to provide all the answers to the many problems which it reviewed, but a good start was made on the more important items, and a number of resolutions were drafted for submission to the Conference of Directors at Washington in September. In order to facilitate the continuation of work on outstanding problems six permanent sub-commissions were formed and the following Presidents chosen:—

Actinometry:	Dr. A. Ångström, Sweden.
Atmospheric optics:	Mr. W. E. K. Middleton, Canada.
Barometry:	Dr. K. Langlo, Norway.
Experimental aerology:	Dr. J. Lugeon, Switzerland
Guide to international meteorological instrument and observing practice:	Dr. F. J. Scrase, United Kingdom.
Station instrumentation and exposure:	Dr. C. F. Brooks, United States.

At the end of the meeting in Toronto, Dr. Patterson was re-elected President of C.I.M.O. and M. E. Papillon was elected Vice-President.

Aerological Commission (President, Dr. S. Petterssen, Norway; United Kingdom delegates, Dr. R. C. Sutcliffe, Secretary, Prof. P. A. Sheppard).—Aerology had a definite meaning in the days when observations in the free atmosphere were few and hard to make, but to-day the methods of observation have been taken over by the instrument specialists and the discussion and interpretation of the results forms the normal field of activity of the meteorological physicist or weather forecaster.

Thus while the Aerological Commission surveyed, during its meetings, the instrumental, observational and operational aspects of world aerology it decided to leave the final consideration of these matters to the appropriate Commissions and to devote the major part of its activity to the scientific and technical use of the collected upper air data.

Some of the matters considered by the Commission were:—

(1) Definitions and specifications of aerological constants and parameters.

(2) Exchange of aerological analyses between neighbouring areas of the world.

(3) Development of a precision radio-sonde.

(4) Value of aircraft reconnaissance flights in obtaining upper air data.

(5) Arrangement of " International aerological days ".

(6) Use of " swarm " radio-sonde ascents in special weather situations.

(7) Frequency and times of routine upper air ascents.

(8) Use of atmospherics-location (sferics) and radar in aerological analysis.

(9) Use of rockets for upper air sounding.

(10) Routine upper air observations on ocean weather ships.

Special mention should be made of the brave attack referred to under (1) above on the problem of the definitions and numerical values of certain physical functions and numerical values used in meteorology. One member of the Commission claimed to have come with a determination to take home a definition of " front ". It is believed that he failed in that object but found he had obtained instead a new definition of relative humidity from which he may have realised the amount of work still ahead.

A sub-commission on aerological diagrams gave international blessing to many such forms of diagrams, and its meetings proved of great educational value.

On the question of the best technique for synoptic representation of the three-dimensional atmosphere rapid agreement was reached on the merits of standard isobaric surfaces. The use of standard pressure levels instead of standard heights has thus achieved international recognition 30 years after its recommendation by V. Bjerknes.

Special lectures and discussions were held at which dynamical theories and methods were the main topic, with much reference to vorticity, divergence, dynamic instability and the like, and relatively little to air masses or the polar front.

(*To be continued.*)

NOTES ON THE I.C.A.N. ALTIMETER AND HEIGHT AND AIR SPEED COMPUTOR

BY G. A. BULL, B.SC.

Part I

Altimeters and their standard atmospheres.—The pressure type of altimeter as distinguished from the radio altimeter, is an aneroid barometer. Changes in the pressure of the air surrounding the aneroid capsule are indicated on a dial in terms of height. An arbitrary relation connecting pressure changes with height changes has to be used for graduating the dial. It is customary to express this relation in terms of temperature as a function of pressure in a theoretical atmosphere which is called the standard atmosphere for the kind of altimeter under consideration. Such theoretical atmospheres seem first to have been used by astronomers in connexion with atmospheric refraction.

An altimeter reads correctly, apart from purely index or instrumental errors, in the standard atmosphere appropriate to it. In any other atmosphere it can only be correct at points such that the harmonic mean temperature between aircraft and ground equals the harmonic mean temperature in the standard atmosphere between the pressures equal to those in the actual one on the capsule and ground.

For many years the standard atmosphere used for altimeters was the very simple one defined by a constant temperature of 50° F. (10° C.). Such an altimeter is bound to have very large errors at great heights because of the high temperature of its standard atmosphere.

For at least the last ten years an atmosphere designed by the International Committee for Air Navigation (I.C.A.N.) has been used generally in altimeter construction though instruments working on the 50° F. atmosphere still exist on light aircraft. These new altimeters were made so sensitive to small pressure changes that a change of height of 10 ft. can be read while improved arrangements were made for setting the zero of pressure and height on the altimeter.

The marks of altimeter used in the R.A.F. constructed to the I.C.A.N. atmosphere are Nos. XIV, XVI, and XVII.

This note deals with the altimeter based on the I.C.A.N. standard atmosphere and its possible errors. The computer used for rapidly obtaining a more nearly correct value of height will be discussed in Part II.

I.C.A.N. standard atmosphere.—The I.C.A.N. standard atmosphere is defined as having a temperature of 15° C. (59° F.) at a pressure of 1013·2 mb., a temperature lapse rate of 1·98° C./1,000 ft. (6·5° C./Km.) up to a pressure of 226 mb., and at pressures lower than 226 mb. a constant temperature of −56·5° C. The acceleration due to gravity, g, is taken to be constant at 980·62 cm./sec./sec. and the value of R, the gas constant for air, to be 2,870,800 C.G.S. units.

From this definition it follows that pressure and height are connected by the formulae,

$$P = 1013{\cdot}2\left(1 - \frac{1{\cdot}98\,H}{288}\right)^{5{\cdot}256} \quad \text{from } P = 1013{\cdot}2 \text{ to } 226 \text{ mb.} \qquad .. \quad (1)$$

$$\text{and } H = 36{\cdot}09 + 47{\cdot}9 \log_{10}\left(\frac{226}{P}\right) \quad \text{at lower pressures} \qquad .. \quad (2)$$

where P is the pressure in mb. and H is the height in thousands of feet above the level at which pressure is 1013·2 mb.

Tables for finding height from pressure in the I.C.A.N. atmosphere or conversely have been published by the National Physical Laboratory and in the Air Ministry Manual of Instruments. The most detailed table, however, is contained in Meteorological Office *Synoptic Divisions Technical Memorandum* No. 31 in which the height is given for every millibar from 1050 to 100 mb.

A brief table for ready reference in connexion with later sections of this note is given in Table I.

U.S.A. standard atmosphere.—In the United States a slightly different standard atmosphere is used.

According to Berry, Bollay and Beer's " Handbook of Meteorology ", it differs in the following respects:—

Temperature		15° C. at 1013·25 mb.
Tropopause	pressure	234 mb.
	temperature	−55° C.
	height	35,332 ft.
Value of g		980·665 cm./sec./sec.

The difference between the two atmospheres is negligible, as Table II shows.

TABLE I—I.C.A.N. ATMOSPHERE

Height	Temperature	Pressure
ft.	° C.	mb.
−1,000	17	1050·3
0	15	1013·2
1,000	13	977·3
2,000	11	942·1
5,000	5·1	843·1
10,000	− 4·8	696·9
15,000	−14·7	571·7
20,000	−24·6	465·4
25,000	−34·5	375·8
30,000	−44·4	300·8
35,000	−54·3	238·2
40,000	−56·5	187·4
45,000	−56·5	147·3
50,000	−56·5	115·9

TABLE II

Height	U.S.A. Pressure	I.C.A.N.
ft.	mb.	mb.
10,000	696·9	696·9
20,000	465·6	465·4
30,000	300·72	300·8
40,000	187·6	187·4
50,000	116·3	115·9

The I.C.A.N. altimeter.—The Mark XIV type of altimeter constructed with the I.C.A.N. atmosphere as standard is shown in the photograph facing p.24. With this type of altimeter the pressure at the level above which it is desired to measure height is set on the instrument by turning the knob at the foot of the dial until the required pressure is seen in the small opening immediately above the knob. This pressure scale, graduated in millibars*, is known as the pressure subscale.

On some types of Mark XIV altimeter pressure can be set within the range 1050 to 800 mb. and on others within the range 1050 to 940 mb.

The height is shown on the circular dial which is graduated from 0 to 10 with each unit subdivided into five subunits. The height is shown by three interconnected hands which rotate clockwise over the dial, the largest hand indicating hundreds of feet, the middle one thousands, and the smallest tens of thousands. The subunits are each of value 20 ft. relative to the largest hand, and the altimeter is sufficiently sensitive to changes in pressure to respond to a change of 10 ft. in height.

The height indicated at any pressure applied to the aneroid capsule is, except for mechanical error, equal to the height interval in the I.C.A.N. atmosphere between the levels at which pressure is subscale pressure and pressure applied to the capsule. The pressure applied to the aneroid capsule of an aircraft in motion differs to a small extent from the static air pressure. The difference is known as position error. It varies with the type of aircraft, and can be allowed for.

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* inches in the case of American altimeters.

The formula for the indicated height is, from equation (1) and because of the principle just stated,

$$H_i = \frac{288}{1 \cdot 98} \left\{ \left(\frac{P_G}{P_0}\right)^{0 \cdot 1903} - \left(\frac{P_H}{P_0}\right)^{0 \cdot 1903} \right\} \quad \ldots \quad (3)$$

where H_i = indicated height in thousands of feet,
P_G = pressure shown on subscale, referred to hereafter as ground pressure.
P_H = pressure applied to aneroid capsule.
P_0 = 1013·2 mb.

Values of H_i for given values of P_G and P_H are readily obtained from a table of heights in the I.C.A.N. atmosphere. For example, if the subscale is set to 977 mb. then at a pressure of 942 mb. the altimeter will read 1,000 ft.

Setting the altimeter for landing.—In landing an aircraft it is desirable that when the aircraft touches down the altimeter should read either zero or the height of the airfield above sea level.

The altimeter can be made to read zero on landing by setting the pressure subscale to the pressure at airfield level which is signalled to the pilot. This pressure is termed QFE in the aircraft signalling code. If the pressure is too low to come in the range of subscale setting pressure this cannot be done, but with an altimeter which can be set down to 800 mb. this is only likely to happen at airfields higher than 5,000 ft. above M.S.L.

If it is desired to make the altimeter read on landing the height of the airfield above M.S.L. the subscale must be set to the pressure at the height in the I.C.A.N. atmosphere found by deducting the height of the airfield from that height in the I.C.A.N. atmosphere at which pressure equals airfield pressure. Thus, if the pressure at an airfield 1,000 ft. above M.S.L. is 942 mb. then the required pressure is the pressure at 1,000 ft. in the I.C.A.N. atmosphere since to 942 mb. corresponds 2,000 ft. The required pressure is thus 977 mb.

American terms for this pressure are " altimeter setting " and " Kollsman number ". The Q-code letters for it are QNH.

At low levels this pressure differs little from the pressure reduced to M.S.L. in the standard meteorological manner, but the difference can amount to a millibar in the case of airfields at 500 ft. and over 2 mb. for an airfield at 1,000 ft.

Table III gives an indication of the differences to be expected between altimeter setting and pressure reduced to M.S.L.

A procedure which can be used if the pressure at airfield level is outside the subscale setting range is to set the subscale to 1013 mb. so that the altimeter reads on landing the height in the I.C.A.N. atmosphere at which the pressure is the airfield pressure. This height, called QFE ALT, QNE in the Q code, is signalled to the pilot.

Setting the altimeter in normal flight, errors of the altimeter.—Normally, for the purpose of avoiding obstacles such as mountain tops it is desirable for the altimeter to read as near as reasonably possible to the true height above M.S.L. This purpose is roughly achieved by setting the subscale to the pressure at mean sea level at appropriate intervals during flight.

It is therefore necessary to consider the magnitude of the errors in the indicated height which are likely to occur owing to the real atmosphere differing from the I.C.A.N. atmosphere. If the subscale is set to the correct sea-level pressure directly below the aircraft the altimeter can only read correctly if the harmonic mean temperature equals the harmonic mean temperature between the same pressures in the I.C.A.N. atmosphere. Since the indicated height is proportional to the harmonic mean absolute temperature in the I.C.A.N. atmosphere and the true height to the actual harmonic mean absolute temperature it follows that the percentage error of the indicated height equals the percentage difference in the harmonic mean temperatures.

TABLE III

Airfield conditions			Pressure reduced to M.S.L.	Altimeter setting
Height	Pressure	Temperature		
ft.	mb.	° F.	mb.	mb.
200	950	30	957·4	957
		60	956·8	957
		90	956·5	957
	1000	30	1007·7	1007·3
		60	1007·2	1007·3
		90	1006·8	1007·3
500	950	30	968·3	967·5
		60	967·2	967·5
		90	966·2	967·5
	1000	30	1019·3	1018·3
		60	1018·2	1018·3
		90	1017·2	1018·3
1000	950	30	987·1	985·3
		60	984·9	985·3
		90	982·9	985·3
	1000	30	1039·0	1036·8
		60	1036·7	1036·8
		90	1034·6	1036·8

If the I.C.A.N. harmonic mean temperature exceeds the actual value the altimeter will read too high and conversely.

The error can be estimated from the following table of the I.C.A.N. harmonic mean temperatures between 1013 and 300 mb.

TABLE IV—I.C.A.N. HARMONIC MEAN TEMPERATURE 1013 MB. TO *P* MB.

P (in mb.)	900	800	700	600	500	400	300
Harmonic mean temperature (in ° K.) ..	284·8	281·6	278·2	274·1	269·5	264	257

Thus the error in height at 30,000 ft. measured from a pressure of 1013 mb. due to actual harmonic mean temperature differing by 1° from the I.C.A.N. value is 30,000/257 = 117 ft.

The errors in indicated height due to deviation of the actual atmosphere from the I.C.A.N. standard have been worked out for four specimen atmospheres. These will be discussed in Part II. The error due to deviation of the actual atmosphere from the I.C.A.N. can be greatly minimised by the use of the height and air speed computor.

Finally, there is the error due to the variation of gravity with height and latitude. The formula for this is:

$$g = 980{\cdot}62(1 - 0{\cdot}00259 \cos 2\phi)(1 - 2H/E) \quad \ldots \quad (4)$$

where H is the height, ϕ the latitude and E is radius of the earth.

We write this expression as

$$g = g_0(1 - a - bH).$$

Since $$\int_P^{P_0} \frac{dP}{P} = \frac{1}{R}\int_0^H \frac{g\,dz}{T_0 - lz}$$

where H is the true height of the level of pressure P above the level of pressure P_0 and temperature T_0 in an atmosphere having I.C.A.N. lapse rate but in which g has its true value which is a function of height, then also

$$\int_P^{P_0} \frac{dP}{P} = \frac{1}{R}\int_0^{H_i} \frac{g_0\,dz}{T_0 - lz}$$

where H_i is the height indicated by an altimeter conforming to the I.C.A.N. law in which gravity has the constant value g_0.

Therefore $$\int_0^H \frac{1 - a - bz}{T_0 - lz}\,dz = \int_0^{H_i} \frac{dz}{T_0 - lz}.$$

Writing $H_i = H + \delta H$, we have

$$\int_0^H \frac{1 - a - bz}{T_0 - lz}\,dz = \frac{\delta H}{T_0 - lH} + \int_0^H \frac{dz}{T_0 - lz}.$$

Hence $$\frac{\delta H}{T_0 - lH} = -\frac{1}{l}\left(a + \frac{bT_0}{l}\right)\log_e\left(\frac{T_0}{T_0 - lH}\right) + \frac{bH}{l},$$

from which the proportionate error $\delta H/H$ is given by

$$\frac{\delta H}{H} = -a - \frac{bH}{2} + \text{smaller quantities.} \quad \ldots \quad (5)$$

In appropriate units $b = 2/E$ while a has a maximum of 0·0026 at the equator. Thus at a height of five miles above the equator the percentage error is − 0·26 − 0·125 = − 0·39 giving an actual error of − 0·02 miles = − 106 ft.

At lower heights and other latitudes, the percentage error will be less. The gravity error δH for any particular height H and latitude can be found from the formula:

$$\frac{H}{H} = -\left(a + \frac{bH}{2}\right) \quad \ldots \quad (6)$$

where $a = 0{\cdot}0026 \cos 2\phi$ and $b = 2/E$, where ϕ is the latitude and E is the radius of the earth.

(*To be continued.*)

AGRICULTURAL METEOROLOGY SECTION OF THE CLIMATOLOGICAL BRANCH

BY L. G. CAMERON, M.SC.

It is in the nature of things that the Meteorological Office—the Central Forecasting Office and the Climatological Branch in particular—should have been to some extent associated with farming and its weather or climate problems since its early years. The office first became really " agriculture-conscious " however, in 1924 when, at the instigation of the late Sir Napier Shaw, the " crop-weather scheme " was initiated. This scheme has resulted in the collection of a mass of meteorological observations which have slightly more bearing on agricultural meteorology than those made at ordinary climatological stations and also in some useful studies of such subjects as frost, but temperatures and humidities are still recorded in Stevenson screens and very little has been done to obtain records at crop level.

By May 1944 the Meteorological Office, aided and, to some extent, prompted by Prof. Sir Edward Salisbury, was seriously considering the question of assistance to agriculture and Prof. Salisbury's " Meteorological requirements of the agriculturalist " was quickly followed by M.R.P.198, a report of the work of the Office in relation to agricultural meteorology. An Agricultural Research Sub-Committee of the Meteorological Research Committee was then formed and a programme of subjects for investigation drawn up.

Early in 1946 the first step was taken with the establishment of a meteorological officer at Cambridge where, working in conjunction with the School of Agriculture he began the first of those investigations which were obviously so necessary. Then the problem of establishing a worth-while and permanent contact with agriculturalists was solved by the attachment of an officer as meteorological adviser to the National Agricultural Advisory Service (N.A.A.S.), at the South-West Province Headquarters at Bristol. Finally, a Headquarters Section was formed at Harrow to handle all agricultural climatological inquiries, conduct research into the climatological aspects of British agriculture, satisfy the requirements of meteorological officers attached to agricultural organizations and generally foster the study of agricultural meteorology in all its aspects.

The problems presented by the study of agricultural meteorology need in most cases an entirely new method of approach. The agricultural meteorologist's world is bounded by the depth of the deepest roots and the tops of the highest trees. In actual practice however this is frequently narrowed down to a layer two or three feet in thickness, for within that layer much of the world's supplies of foods and vegetable raw materials and the pests which attack them live and grow. We have in limited numbers soil temperatures down to 4 ft., but long-period information of conditions within the lowest 2–3 ft. of the earth's atmosphere, apart from grass-minimum temperatures and some scanty evaporation data, simply does not exist. So we are faced not merely with a lack of precise information of conditions in the region which concerns us most but also with the fact that this same region also happens to be the atmospheric layer in which the most fundamental variations of temperature, humidity and wind occur. Screen temperature and humidity data, of which there are a superabundance, bear little or no relation to conditions two inches above the ground, whilst to compare directly, the wind at anemometer level with the movement of air at 1 ft. through a wheat field or orchard would be ludicrous. This problem of relevant data, has not been solved and can never approach a solution unless we superimpose upon the present system of standard climatological observations a series of agricultural meteorological observations specifically designed to satisfy the special requirements of the subject.

The question of forecasting comes next to one's mind. This is the branch of meteorology in which the farmer has been best served for many years. He can, and could even before this last war, avail himself of the general forecast facilities either as a member of the public or by taking advantage of the scheme whereby, for a small sum, he can register his requirements with the Forecast Branch and receive forecasts giving special attention to whatever farming operation, such as harvesting, sowing or spraying, he has in mind. In addition, of course, there are the broadcast forecasts and frost warnings on which he has learned to place a certain reliance. In spite of this there is room for a good deal of improvement on both sides. For our part it is desirable that the country be divided into smaller forecast regions thus making it possible for separate consideration to be given, for instance, to the requirements of the horticultural district of south-west Cornwall and those of the apple-orchards region of Devon. In effect it means of course that local climates be given the full weight of their importance to that patchwork of specialised interests which is British agriculture. From the farmer we ask for the careful perusal of all the information supplied to him, and, since it is not yet possible to cater for every small area and interest, the intelligent application of that information, in the light of his own local knowledge, to his own small part of the country.

Direct contact with the specialists of the N.A.A.S. was most fruitful and the meteorological officer's work at Bristol very quickly unearthed many agricultural problems on which meteorology has a direct bearing. A few examples may serve to illustrate this fact. The ordinary aphide or greenfly, a nuisance to all keen gardeners, is also a major enemy of seed-potato growers and can, given free rein, completely ruin a year's crop. It appears that this insect is the carrier of a virus which when transmitted to the potato haulm causes potato leaf roll and other virus diseases some of which affect the potato itself only in the year after the initial contact. Obviously if the potato industry is to be safeguarded then aphide movement must either be controlled or areas found where its activity is restricted. Now, the aphide's flight is influenced by certain meteorological factors of which temperatures of less than 65° F., relative humidities of more than 70 per cent. and wind speeds greater than 5 m.p.h., all at potato-top height, appear to be critical. Here then was one of our first major problems—that of finding areas where the above conditions prevail during the months of aphide activity and so, in effect, locating regions most suited to the growth of seed potatoes. Other problems, embracing practically every branch of agriculture, include the chocolate-spot disease on beans—a temperature, humidity and rainfall question—the testing of milk in commercial laboratories, the artificial drying of hay and grain, the spraying of fruit and other crops, the frosting of orchards and small fruit plantations, the effects of exposure on farm animals, the influence of cow-shed temperatures and other factors on the "solid-not-fat" content of milk, the climate of a greenhouse and innumerable other kindred questions. All have a meteorological background which needs investigating.

The larger problems of local climates and microclimates are not being forgotten. Local climates must be studied to indicate areas most suited to specialised crops, whilst the investigation of microclimates is continually forcing itself upon us, as in the case of the chocolate-spot disease where we cannot hope to make much progress until we know the microclimatic conditions operating between the individual plants and rows of various spacings. Small microclimatic studies in connexion with the drying of hay have been initiated, in the south-west, recently, by the meteorological officer at Bristol.

It is obvious to everyone that progress in agriculture is to some extent dependent upon advancement in meteorology, but experience has shown that the plane of contact between these two sciences is far more extensive than one might expect. The problems of agriculture are legion and agricultural meteorology must accept the responsibility of contributing to their solution.

METEOROLOGICAL RESEARCH COMMITTEE

The 52nd meeting of the Meteorological Research Committee was held on December 4, 1947. At that meeting it was decided to form three sub-committees to deal respectively with questions relating to (*a*) instruments, (*b*) forecasting and (*c*) physical and dynamical matters.

The Secretary read a letter from Prof. Duperier in which the latter expressed the opinion that cosmic-ray data are entirely consistent with some recent analysis of upper air temperatures which indicate a substantial diurnal variation of temperature at heights of the order of 15 Km. It was decided to consider this matter further at the next meeting.

A paper discussing the accuracy of speed corrections to aircraft thermometers was presented by Dr. Frith.

Two papers dealing with radio-sonde observations were read: one compared the GL.IIIB with the S.C.R.658 for wind-measurement purposes, and the other dealt with the relative advantages of radio-sonde and radar methods of determining the heights of significant points.

On the subject of turbulence in the lower atmosphere a tentative proposal for a new way of computing the turbulent transport of particulate matter was put forward.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society, held at 49, Cromwell Road, on December 17, Prof. G. M. B. Dobson, President, in the Chair, a motion was adopted to elect each year an additional Vice-President for Scotland and an additional Vice-President for each Overseas Branch of the Society that is formed. Then the following papers were read:—

J. A. Chalmers—The capture of ions by ice particles

C. T. R. Wilson suggested in 1929 that a factor producing a separation of charge in thunderclouds was preferential capture of ions of one sign by the falling water drops polarised under the influence of the vertical electric field. Whipple and Chalmers worked out the theory mathematically in 1944.

In the present paper, Dr. Chalmers considered the same ideas as applied to ice crystals. He pointed out that, owing to the high dielectric constant, crystals of ice would become polarised with charges of the same sign, but smaller magnitude, as conducting particles of the same shape would acquire in the same electric field. The essential distinction between water and ice particles is that charges reaching water drops are spread over the whole surface while those reaching a non-conductor such as ice stay where they arrive. The results of his earlier paper on water drops were then derived in a simpler way than in that paper, and the new method applied to find the rate at which a falling spherical piece of ice would accumulate charge by impact with ions.

Flat ice crystals are dealt with in a similar way but in their case there is the complication of overturning which changes the sign of the induced charges leaving the charges accumulated by contact with ions unchanged. After a brief reference to conditions below clouds Dr. Chalmers considered the main problem of the separation of charge within clouds. The argument is based on the mobilities of large and small ions in electric fields approaching the critical sparking value of 10,000 volts/cm. and the general result is that in all cases the Wilson mechanism is unable to provide an electric current sufficient to explain the observed rates of change of the electric field. In particular it is unable to explain the rapid recovery of field after a lightning flash which begins at a time when there is little electric field to produce the necessary initial polarization.

Dr. Chalmers illustrated his lecture with tennis and ping-pong balls and a piece of card representing hailstones, ions and ice crystals respectively, suitably coloured to indicate the sign of charge.

In the discussion, Dr. F. J. Scrase said the results of the paper would be of value in connexion with the modern theory of the formation of rain, and suggested that radar methods might throw light on the electrical structure as well as the physical structure of clouds.

Dr. T. Wormell, asking whether ice crystals really are perfect non-conductors, said only a small degree of conductivity was needed to make the crystals behave as conductors so permitting the rapid dispersion over the crystal of ionic charges picked up. He also thought the spherical hailstones were unlikely to fall for any distance without turning over since the charge distribution on them was such as to produce an electric couple tending to invert the drop if there were the least displacement from the position of equilibrium.

Dr. Scrase said he thought radar reflections from clouds definitely showed ice crystals to be non-conductors.

R. C. Rainey—Observations on the structure of convection currents: meteorological aspects of some South African gliding flights

In the absence of the author a summary of this paper was given by Mr. F. K. Miles. The paper was concerned with the data obtained during the South African Gliding Contest held near Pretoria in October 1938. First, the paper showed that the maximum height reached by gliders agreed closely with the height of the point of intersection on the tephigram of the dry adiabatic line through the observed screen temperature with the environment curve measured by a nearby aircraft sounding. Three graphic examples were given.

Secondly, the experiences of gliders in the forced flow of air over a steep ridge were used to show a high correlation between the heights reached and the component of wind perpendicular to the ridge.

Thirdly, the ascending and descending currents of air encountered by gliders during long flights on days of convection gave a picture of convective cells of horizontal extent about twice their depth, and of about two miles length downwind, providing an approximate value of the masses of ascending and descending air within a given isobaric slice.

Finally, the author showed examples of flights made in the warm air ahead of a well marked cold front, which gave very much stronger rising currents than could be produced by forced ascent due to undercutting of the warm air by the front and which could only be accounted for as convection currents connected with instability in the unstable warm air concentrated into a narrow zone just ahead of the cold front instead of being scattered over a large area. Observed temperatures showed the warm air to be highly unstable.

In the discussion, Dr. Slater said the air near the ground would not rise as a " thermal " until it was 1° C. warmer than the surrounding air and this higher temperature taken along the dry adiabatic led to an appreciably greater height than that obtained from the ordinary screen temperature. This fact might account for the height reached exceeding somewhat on occasion the height found from the recorded ground temperature. He doubted whether calculations of the component of wind up the slope could be made when the general wind was oblique since the air then appears to have a roller-like motion with axis over the crest. On the question of convection cells, he said, glider pilots thought warm air went up in bubbles rather than in the streams favoured by meteorologists, while for the cold-front effects he was inclined to favour Lange's view that convection ahead of cold fronts was associated with diffusion of cold air above warm air rather than instability in the warm air itself.

Mr. H. H. Lamb agreed that undercutting by cold air could not produce appreciable rising currents by itself, mentioning that in the course of long experience in the construction of vertical sections he had found the maximum slope of a cold front was 1/17. He also asked what allowance was made for the pilot's skill in assessing the height reached in relation to turbulence.

Mr. Gold said he was puzzled by the absence of any reference to water vapour, pointing out that on the first occasion shown in the tephigrams the surface air would, after reaching the condensation level, have gone up in cloud along the saturated adiabatic to a much greater height.

Mr. Miles, in reply, said it was reasonable to assume that the heights referred to were reached by a skilful pilot able to keep the glider in the thermal so long as it lasted. He agreed with Mr. Gold that the effects of water vapour ought to have been considered.

R. W. Hatcher and J. S. Sawyer—Sea-breeze structure with particular reference to temperature and water-vapour gradients and associated radio ducts

Mr. Sawyer, in presenting this paper, gave a brief but clear description of results which had been obtained from special aircraft observations, to examine as closely as possible the temperature and humidity structure of sea-breeze conditions when anomalous radio propagation was likely, made by Hurricanes of No. 1302 Met. Flight, based at Madras on the east coast of India, in April and May 1945. Each set of observations was made by a single aircraft, and the time taken varied from 15 minutes to just over one hour.

The conditions necessary for the formation of a radio duct, or region of super-refraction of radio waves, were either a steep inversion or a steep lapse of water vapour density. The observations (taken on occasions during the afternoon when the sea breeze would be likely to be at its greatest development at intervals varying from three to ten miles horizontally and 200 to 1,000 ft. vertically) showed fairly conclusively that the temperature inversion was not steep enough to form a radio duct, whereas the lapse of water vapour density was more than sufficient. Mr. Sawyer then showed some idealised cross-sections (based on the observations at Madras when there was an upper wind over the sea breeze from land to sea) of typical distributions of potential temperature and water vapour density and of the probable forms of radio duct and stream-lines during the sea breeze.

The investigation provided evidence of the surface radio duct but not of the elevated duct which had been suggested by Dr. Booker; it also suggested the existence of marked turbulence over the coast and only slight subsidence in at least the first 20 miles over the sea.

In the discussion, Dr. Robinson drew attention to Fig. 3 (*b*) in which he pointed out that if the curve showing variation of water-vapour content had been drawn without smoothing there would have been a possible elevated radio duct just below 2,000 ft. A glider pilot present, Mr. L. Welch, mentioned an experience he had had when gliding near Weymouth: he found an upcurrent some few miles off the coast which he had not expected and was in some doubt as to whether to glide further out to sea in the hope of finding it stronger or to come inland again.

In reply, Mr. Sawyer doubted whether the 200-ft. thickness of suitable conditions was enough to cause a radio duct; he admitted there was not firm justification for smoothing the curve in Fig. 3 (*b*). He could offer no explanation of the upcurrent off the coast of Weymouth.

LETTER TO THE EDITOR

Unusual condensation trails

The following phenomenon was reported by F/Lt. H. S. Smith on November 29, 1947, to Mr. Ripley, Meteorological Officer of West Malling:—

Whilst carrying out the meteorological ascent over West Malling at 1100 G.M.T. on that day, condensation trails of an unusual type occurred. The aircraft concerned was a Mosquito, and from 400 mb. to the top of the climb (300 mb.) dense persistent trails were formed by the propellers. The condensation trails were most dense near the centre of each trail. The wings immediately behind the propellers were immersed in the trails and clear ice formed slowly on the leading edge, later spreading back over the wings. There was no cloud at these heights and no ice formed on the aircraft except where immersed in the condensation trails. The corrected air temperatures were − 47° F. at 400 mb., − 60° F. at 350 mb., and − 72° F. at 300 mb.

As far as can be ascertained, no other authentic record of this kind of condensation trail exists. Records of condensation-trail formation over a wide range of conditions and with a large variety of aircraft were amassed during the war without this type being recorded. It can therefore be regarded as both interesting and unusual.

The following note on the synoptic situation on November 29, 1947, has been given by Mr. C. K. M. Douglas:—

A damp air mass probably covered south-east England at about 400 mb. (relative humidity 90 per cent. reported at Downham Market) and could be related to a precipitation area further eastward. The centre of an occluded depression was just east of Brussels at the surface, but was displaced westward aloft and gave a poorly defined centre over south-east England in the 400–300 mb. layer. There was a cold unstable layer over south-east England up to 10,000 ft. and above that a stable layer with a considerable increase of wet-bulb potential temperature. The wind was light and indefinite in the region where the condensation trails formed. The air mass was nearly saturated and at the boundary of an old frontal cloud system.

C. J. M. AANENSEN

NOTES AND NEWS

An old method of obtaining water from the air in dry localities

The problem of getting drinking water from the air by means of artificial condensation of water vapour is important especially in areas of steppes and deserts or key points like Gibraltar.

Siebold, a Russian, while working on the slopes of a mountain range near the ancient Crimean town Theodosia*, uncovered the remains of several huge cones of coarse pebbles of similar size built on solid bases. Some primitive clay-made pipelines were also found connected to some derelict wells at Theodosia. Altogether 8,400 segments of pipelines were recovered during the period 1831–3.

Siebold considered this idea of unknown builders to be as clever as it was simple.

The air is cooled by evaporation as it filters through the cones, and is cooled down to its dew point in the lower part. The surfaces of all the pebbles gave a total surface of an immense size so that a cone was able to provide an appreciable amount of water to the well. The idea may be compared to that of a dew pond employed in southern England.

To prove his conclusion, Siebold had built on a pass of the Tepe-oba range in Crimea a single truncated cone 20 ft. high, with a base 60 ft. in diameter and a top 24 ft. in diameter. The building of the cone was finished in 1912 and gave 36 " buckets " of water a day (equivalent to 80 gallons) even on rainless days. It ought to be mentioned that the district of Theodosia is situated in the lee of a mountain range and practically out of depression tracks. Its annual rainfall does not exceed 25 in. a year but owing to the proximity of the Black Sea, the content of moisture in the air is relatively high.

After a time the cement base of Siebold's cone broke and the outbreak of the first world war prevented further experiments.

In 1934 however, the Central Institute for Experimental Hydrometeorology in Moscow called a conference on December 3. Prof. Tugarinov, S. V. Gorbacev, B. A. Apollov, B. P. Orlov, A. V. Voznesenskij and V. V. Danilevskij gave a series of lectures on the subject of artificial condensation of water vapour from the air and its importance for national economy and defence.[*] A permanent Committee was set up to develop Siebold's idea.

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* News summary. Wiad. met. hydrogr. Warsaw, 1936, Nos. 7-9, p. 95.

At much the same time French authorities, concerned with the problem of water supply to projected trans-Saharan Bus Communication, made experiments on the subject, but the final results are unknown.

The building of an experimental type of similar cone or condenser was started in Poland in 1939 at the Meteorological observatory on Pop Iwan (6,640 ft.), but the outbreak of the second world war prevented its development.

Unfortunately, no details are available of the type of pebbles used. A mixture of pebble and coarse gravel may help in intensifying the whole process. The greatest possible exposure to air currents is undoubtedly important.

W. MIDOWICZ

[This appears to be a case of collection of mist particles rather than of condensation as dew. The following similar cases are of interest in this connexion.

On the Desertas (islands some 12 miles from Madeira), which are streamless and springless, fishermen live by water obtained by spreading out fleeces in the evening, and wringing the dew from them in the morning.[†]

Marloth exposed two 5-in. rain-gauges on Table Mountain, one in the ordinary way and the other having a number of reeds fixed in such a way that any moisture deposited on them dripped into the gauge. Within two months the first rain-gauge collected 4·9 in. of rain and the second 70·8 in. During the first ten days of this period, whilst the first gauge collected nothing, the second collected 15·2 in.[‡]

In the island of Ferro (Hierro), in the Canaries, the condensation on the leaves of one special tree (known as the Garoe or Til and situated in the declivity of a hill) used to be collected into two cisterns beneath the tree in such quantities as to supply drinking water from one of the cisterns and water for cattle, washing and such-like purposes from the other.[§]—C. E. P. BROOKS]

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[*] Stenogramma Pervoj Konferencii po Kondensacii vodjanych parov voxducha. Moscow, 1935.

[†] HUBBARD, A. J. and HUBBARD, G.; Neolithic dew ponds and cattle-ways. London, 1907, p. 115.

[‡] MARLOTH, –.; Results of experiments on Table Mountain for ascertaining the amount of moisture deposited from the south-east clouds. *Trans. S. Afr. phil. Soc. Cape Town*, **14**, 1903–4, p. 403 and **16**, 1905–7, p. 97.

[§] HUTCHINSON, J.; The rain tree of Hierro, Canary Islands. *Kew Bull. London*, No. 3, 1919, p. 153.

Snow rollers

Snow rollers were formed at Full Sutton, Yorks, on January 10, 1945, during a rather prolonged snow shower which lasted from 0830 to 0925 G.M.T. Before the shower commenced the ground was covered by an even layer of snow, 2 to 3 in. deep.

The intensity of the snow was generally slight, though increasing to moderate at times. The surface wind was NW. 5 m.p.h., the air temperature 28·9° F. and the dew point 27·9° F.

The photograph facing p. iii of cover was taken about an hour after the shower ceased, there being no further snow during the interval.

The number of rollers formed was extremely large both on the open space of the airfield and also in the rather more sheltered fields close by.

In shape the rollers were cylindrical and hollow at both ends. They were composed of several layers each being about 2 inches thick. The rollers varied considerably in dimension, the largest being up to 3 ft. long and 1 ft. 6 in. in diameter. Leading to each roller was a trough from which the snow forming the roller had been removed. The trough broadened the nearer it got to the roller, indicating that there was gradual growth both in length and diameter.

The snow was loosely packed and the rollers disintegrated at the slightest rough handling, also when the wind speed increased to 15 m.p.h.

It is interesting to note that in a later snow shower with a wind of 10 m.p.h. and a temperature of 34° F., further rollers were not formed.

Unfortunately the photograph had to be taken in very poor light, 10-tenths thick cloud obscuring the sun. A close-up of a roller was also taken but this photograph proved a failure.

G. BUNTING

REVIEWS

A hőmérséklet szerepe a rovarok életében (Effects of temperature on the life of insects), by G. A. Manninger. *Időjárás, Budapest.* **51**, 1947, pp. 75–8 (English summary, p. 103).

This paper, in the Hungarian meteorological journal, is of special interest to agricultural meteorologists in this country in that it describes work which bears a close relationship with our own recent research on the meteorological aspects of aphide activity.

After dealing with the fact that insects possess only limited means of heat regulation the author proceeds to illustrate this by a curve in which insect activity is plotted as a function of the temperature. He further demonstrates the importance of temperature as a control in insect development by reference to the development of generations of the gallfly of alfalfa buds, and also by a neat graphical illustration of the decline of the European corn-borer (Pyrausta nubilalis Hühn) during the months of June and July, 1945, when temperatures were well below average. His concluding remarks, to the effect that in Hungary owing to its continental climate insect damages to crops are of the utmost importance, can also apply with equal force to this country.

Dr. Manninger's final contention that the practical application of meteorology to these entomological problems promises to open the way to the prevention of insect damage to crops is perhaps somewhat optimistic. At this stage we feel that it would be more prudent to think in terms of a large-scale reduction of insect damage rather than of its complete elimination.

L. G. CAMERON

Polar lights, by C. M. Botley. 8vo. 8½ in. × 5½ in. pp. 31 *Illus.* Obtainable from the author, 2, Park Road, Tunbridge Wells. 1947. Price 3*s*.

This booklet is addressed to those people who regard things animate and inanimate " with an interest which has in it something of affection ". The author sets out to bring to light some of the knowledge of the aurora polaris which has hitherto remained buried " in the pages of learned journals or ponderous text books ", and on the whole she has succeeded in presenting this knowledge in a very readable form.

The first chapter is a brief historical survey of references to the aurora in such widely different books as the Bible and Shakespeare's " Julius Caesar ", and contains some amusing accounts of ancient beliefs about the aurora and what is portended. More modern descriptions of the aurora and theories about its origin are dealt with in the second chapter. Many memories will be stirred by the accounts of the great displays of March 23, 1946, and more especially January 25, 1938. Such controversial subjects as the possibility of hearing the aurora and of its occurrence in the lower layers of the atmosphere are ably covered. In the last chapter advice is given to those who wish to observe the aurora and keep a scientific record of their observations.

The only illustration is a drawing of a corona seen in Cumberland on April 23, 1946. It is a pity that it was not possible to include a few photographs of the more definite auroral forms. Failing this, reference should have been made in the note on " Further reading " to the excellent " Photographic atlas of auroral forms " published by the International Geodetic and Geophysical Union, which many regard as an indispensable book for anybody making a serious study of the aurora. A brief reference to the recent exciting possibilities of producing artificial aurora (a patent has been taken out to cover the use of artificial aurora as a possible form of street lighting) would also have enhanced the value of this otherwise very fascinating little book.

O. M. ASHFORD

NEWS IN BRIEF

On November 28, 1947, at 7 p.m., Mr. Seton Gordon observed a particularly fine lunar rainbow spanning Nig Bay in the Isle of Skye. Mr. Gordon has frequently seen lunar rainbows, " but never one with an equal brilliance, the colours being almost as clear and striking as those of a solar rainbow ". About 15 minutes later when Mr. Gordon was at a different part of the road, a second lunar rainbow formed of less strength than the first.

WEATHER OF NOVEMBER, 1947

During the greater part of the month pressure was high over the Arctic, especially Greenland, and over Spain or southern Europe. Between these two anticyclones a series of depressions, some of them intense, passed between Scotland and Iceland. On the 3rd pressure fell below 976 mb. between the Faroes and Shetlands, and on the 22nd–23rd below 964 mb. south and east of Iceland. These unsettled conditions were interrupted on 6th–7th and 15th-19th when the two anticyclones united in a ridge of high pressure across Britain, bringing cold spells. The second of these ended abruptly on the 20th when a deep depression in mid Atlantic brought a stream of very mild tropical air over Britain. Cold conditions returned on the 24th when high pressure extended over the Atlantic west of these islands in the rear of a depression over Europe.

The pressure map for the month as a whole shows high-pressure areas exceeding 1025 mb. centred over north-east Greenland and central Spain, separated by a trough below 1005 mb. running east-north-east from 50° N. 30° W. to central Norway. Pressure was 12 mb. above normal over Greenland, Jan

Mayen and Spitsbergen, 7 mb. below normal over the Baltic countries and as much as 15 mb. below normal in mid Atlantic west of the Azores.

Temperatures were generally several degrees above normal in Spain and central Europe but below normal in Scandinavia and Greenland; Oslo, with a mean for the month of 27° F., was 5° F. below normal, and Myggbukta in north-east Greenland (mean: − 7° F.) was 10° F. below normal. Precipitation was generally deficient in Spain and the western Mediterranean but Lisbon had the unusual total of 13 in. compared with a normal of only 5 in.

The weather over the British Isles was distinguished by strikingly large and rapid fluctuations of temperature. The first twelve days were mild and unsettled but cold polar air in the rear of a depression over the Baltic on the 13th was the prelude to a very cold spell. Considerable snow fell in the north of Scotland from the 15th–17th while a secondary depression moving east-south-east from south-west Ireland caused widespread snow and sleet in England and Wales on the 18th. Very low minimum temperatures were recorded locally on the 19th, for example, 1° F. at Dalwhinnie and 3° F. at Braemar. By the 20th, however, tropical air from southward of the Azores in front of a large and complex depression on the north-east Atlantic was drawn in over the British Isles; this air current was excessively mild and humid and temperature rose by 15° to 25° F. or more in 24 hours. There was thus no gradual warming of buildings and water streamed down their inside walls. In the west and north unusually heavy rain also occurred, notably 6·28 in. at Glenquoich, 4·45 in. at Kinlochourn and 4·24 in. at Erracht all in Inverness-shire. The rapid thawing of the snow together with torrential rains caused severe flooding in Lochaber. A few very mild days ensued but on the 24th another influx of cold polar air caused a very rapid fall of temperature and cold showery weather with bright periods persisting until the end of the month.

Mean temperature for the month exceeded the average except in the north of Scotland where it was slightly below the average. Broadly speaking rainfall increased north-westward from less than 50 per cent. of the average in an area extending from south of Cambridge to the Sussex coast and locally in Hampshire to more than 175 per cent. in Snowdonia, the western Pennines, locally in Cumberland and in a fairly large area from the Moray Firth to near the west coast of Scotland. The month was notably sunny in most districts. There was a deficiency, however, in the neighbourhood of the Moray Firth and in parts of Wales and south-west and south England. Widespread fog occurred in England and Wales on the 6th–7th and caused considerable dislocation of traffic.

The general character of the weather is shown by the following table:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	65	14	+2·1	87	−1	126	29
Scotland	63	1	0·0	139	+2	131	28
Northern Ireland	62	23	+2·0	153	+3	128	31

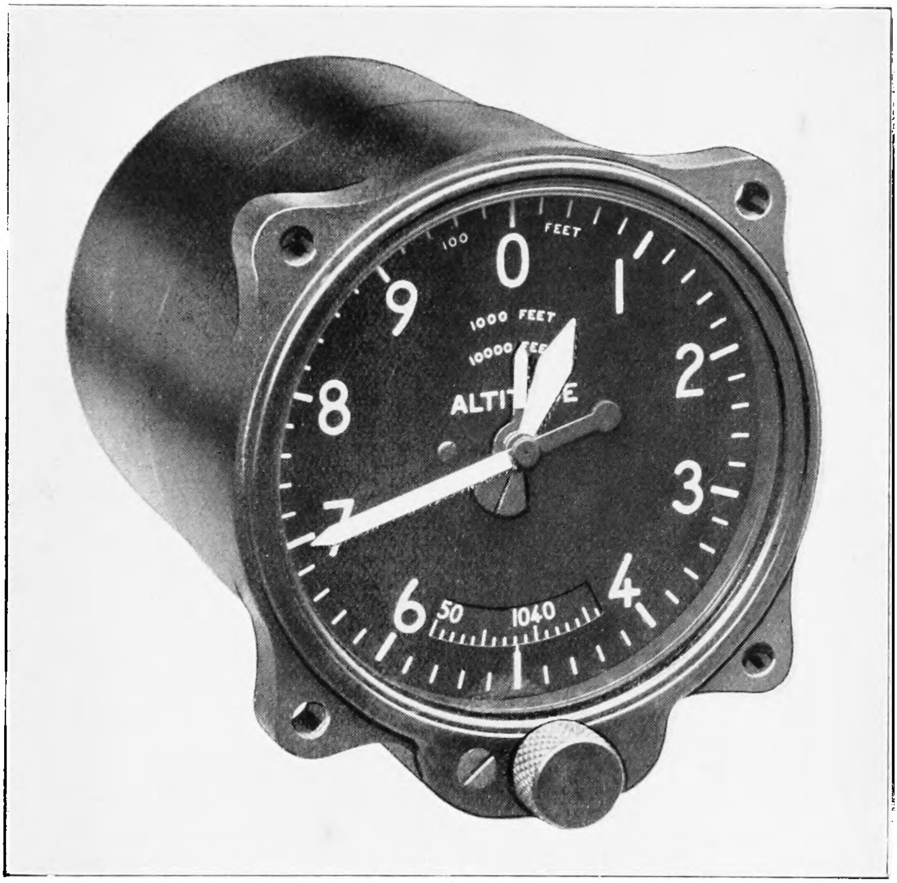
RAINFALL OF NOVEMBER 1947

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1.01	43	*Glam.*	Cardiff, Penylan	4.70	116
Kent	Folkestone, Cherry Gdns.	2.30	71	*Pemb.*	St. Ann's Head.. ..	4.77	119
„	Edenbridge, Falconhurst	1.38	39	*Card.*	Aberystwyth	3.67	99
Sussex	Compton, Compton Ho.	1.95	51	*Radnor*	Bir. W. W., Tyrmynydd	6.84	103
„	Worthing, Beach Ho. Pk.	1.39	43	*Mont.*	Lake Vyrnwy	9.18	158
Hants.	Ventnor, Roy. Nat. Hos.	2.34	73	*Mer.*	Blaenau Festiniog ..	20.09	189
„	Fordingbridge, Oaklands	1.42	42	*Carn.*	Llandudno	4.13	143
„	Sherborne St. John ..	1.65	58	*Angl.*	Llanerchymedd ..	4.51	107
Herts.	Royston, Therfield Rec.	1.17	50	*I. Man.*	Douglas, Boro' Cem. ..	7.06	150
Bucks.	Slough, Upton	1.19	54	*Wigtown*	Port William, Monreith	6.01	139
Oxford	Oxford, Radcliffe ..	1.26	55	*Dumf.*	Dumfries, Crichton R.I.	4.70	128
N'hant	Wellingboro', Swanspool	1.41	66	„	Eskdalemuir Obsy. ..	8.68	150
Essex	Shoeburyness	.87	41	*Roxb.*	Kelso, Floors	2.87	124
Suffolk	Campsea Ashe, High Ho.	1.48	67	*Peebles.*	Stobo Castle	4.74	143
„	Lowestoft Sec. School ..	1.41	60	*Berwick*	Marchmont House ..	2.66	89
„	Bury St. Ed., Westley H.	1.46	63	*E. Loth.*	North Berwick Res. ..	2.29	102
Norfolk	Sandringham Ho. Gdns.	1.45	58	*Midl'n.*	Edinburgh, Blackf'd. H.	2.90	129
Wilts.	Bishops Cannings ..	1.80	63	*Lanark*	Hamilton W. W., T'nhill	5.61	157
Dorset	Creech Grange ..	2.74	62	*Ayr*	Colmonell, Knockdolian	6.05	121
„	Beaminster, East St. ..	2.35	59	„	Glen Afton, Ayr San. ..	8.20	149
Devon	Teignmouth, Den Gdns.	2.12	66	*Bute*	Rothesay, Ardencraig ..	7.45	147
„	Cullompton	2.82	82	*Argyll*	Loch Sunart, G'dale ..	9.63	129
„	Barnstaple, N. Dev. Ath.	3.27	83	„	Poltalloch	..	..
„	Okehampton, Uplands	4.16	78	„	Inveraray Castle ..	14.04	166
Cornwall	Bude School House ..	2.70	76	„	Islay, Eallabus	8.33	155
„	Penzance, Morrab Gdns.	3.55	78	„	Tiree	5.85	121
„	St. Austell, Trevarna ..	4.99	101	*Kinross*	Loch Leven Sluice ..	3.91	109
„	Scilly, Tresco Abbey ..	2.96	86	*Fife*	Leuchars Airfield ..	1.75	76
Glos.	Cirencester	1.83	61	*Perth*	Loch Dhu	12.48	144
Salop	Church Stretton ..	2.41	78	„	Crieff, Strathearn Hyd.	4.45	103
„	Cheswardine Hall ..	2.20	85	„	Blair Castle Gardens ..	4.64	132
Staffs.	Leek, Wall Grange, P.S.	3.73	120	*Angus*	Montrose, Sunnyside ..	1.98	75
Worcs.	Malvern, Free Library	2.14	85	*Aberd.*	Balmoral Castle Gdns...	3.28	89
Warwick	Birmingham, Edgbaston	1.87	79	„	Aberdeen Observatory	2.80	94
Leics.	Thornton Reservoir ..	2.02	89	„	Fyvie Castle	4.04	117
Lincs.	Boston, Skirbeck ..	1.09	55	*Moray*	Gordon Castle	5.31	184
„	Skegness, Marine Gdns.	1.30	60	*Nairn*	Nairn, Achareidh ..	3.85	171
Notts.	Mansfield, Carr Bank ..	1.85	76	*Inv's*	Loch Ness, Foyers ..	8.42	216
Ches.	Bidston Observatory ..	3.25	130	„	Glenquoich	21.75	179
Lancs.	Manchester, Whit. Park	3.76	142	„	Fort William, Teviot ..	13.98	170
„	Stonyhurst College ..	7.67	170	„	Skye, Duntuilm ..	8.17	136
„	Blackpool	3.80	110	*R. & C.*	Ullapool	7.90	153
Yorks.	Wakefield, Clarence Pk.	2.00	94	„	Applecross Gardens ..	9.00	139
„	Hull, Pearson Park ..	1.43	65	„	Achnashellach	15.28	177
„	Felixkirk, Mt. St. John	2.02	82	„	Stornoway Airfield ..	7.65	138
„	York Museum ..	1.40	67	*Suth.*	Lairg	5.26	132
„	Scarborough	2.11	85	„	Loch More, Achfary ..	14.46	169
„	Middlesbrough.. ..	1.72	81	*Caith.*	Wick Airfield	5.05	161
„	Baldersdale, Hury Res.	5.27	142	*Shet.*	Lerwick Observatory ..	5.67	133
Nor'ld	Newcastle, Leazes Pk.	2.51	107	*Ferm.*	Crom Castle	5.27	151
„	Bellingham, High Green	4.27	124	*Armagh*	Armagh Observatory ..	4.00	141
„	Lilburn, Tower Gdns. ..	3.01	90	*Down*	Seaforde	4.04	107
Cumb.	Geltsdale	4.72	144	*Antrim*	Aldergrove Airfield ..	3.82	118
„	Keswick, High Hill ..	10.11	179	„	Ballymena, Harryville	6.07	150
„	Ravenglass, The Grove	5.07	113	*Lon.*	Garvagh, Moneydig ..	6.58	167
Mon.	Abergavenny, Larchfield	3.45	90	„	Londonderry, Creggan	8.01	195
Glam.	Ystalyfera, Wern House	8.44	128	*Tyrone*	Omagh, Edenfel .	7.47	197

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, JULY 1947

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily Mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1015·0	−0·9	85	51	72·7	58·5	65·6	+2·6	60·3	75	8·2	1·41	−0·76	13	4·7	29
Gibraltar	1015·3	−1·5	87	64	83·6	69·6	76·6	+1·8	71·0	79	3·0	0·10	—	2	—	—
Malta	1013·3	−1·4	94	68	87·6	71·7	79·7	+1·4	72·7	58	1·9	0·23	—	2	11·7	82
St. Helena	1019·3	−0·8	64	52	60·6	53·9	57·3	−1·0	54·4	96	9·7	4·18	+0·05	25	—	—
Freetown, Sierra Leone	1014·3	+3·3	88	70	83·0	73·8	78·4	+1·5	75·2	89	8·8	35·69	+0·11	28	3·2	26
Lagos, Nigeria ..	1013·9	+0·7	86	67	81·6	71·1	76·3	−1·7	74·6	91	9·5	13·66	—	16	1·8	15
Kaduna, Nigeria ..	1012·1	—	88	64	83·4	68·1	75·7	+1·5	70·9	84	9·1	7·76	−2·86	20	5·4	43
Chileka, Nyasaland																
Salisbury, Rhodesia ..																
Cape Town ..	1021·0	−0·3	74	39	60·9	47·7	54·3	−0·4	49·0	85	6·7	7·71	+4·09	20	—	—
Germiston, South Africa	1024·5	—	69	24	60·2	33·5	46·9	—	36·1	42	1·9	0·06	—	4	9·4	89
Mauritius																
Calcutta, Alipore Obsy.	998·1	−0·8	95	78	90·1	79·7	84·9	+1·2	79·9	88	8·8	16·04	+3·34	27	3·7	28
Bombay	1003·1	−0·8	92	72	86·8	77·6	82·2	+0·8	78·2	87	9·3	22·03	−2·24	31	—	—
Madras	1004·2	−0·3	99	71	94·9	79·2	87·1	−0·5	75·4	70	8·9	4·74	+0·90	9	3·9	30
Colombo, Ceylon ..	1009·1	0·0	88	74	86·1	77·1	81·6	+0·4	76·6	84	7·6	7·06	+2·63	19	6·4	51
Singapore	1008·9	0·0	93	73	87·9	74·6	81·3	0·0	78·1	82	—	5·04	−1·75	10	—	—
Hongkong	1006·0	+1·3	90	74	87·1	77·8	82·5	0·0	78·8	88	—	22·82	+8·40	25	5·3	40
Sydney, N.S.W. ..	1016·5	−1·8	71	39	62·8	46·1	54·5	+1·8	46·5	68	3·2	0·55	−4·25	8	7·3	71
Melbourne	1014·7	−4·2	62	37	56·2	44·8	50·5	+1·8	45·8	76	7·4	3·71	+1·85	19	2·7	28
Adelaide	1017·6	−2·6	64	38	58·2	46·0	52·1	+0·2	47·1	76	8·3	2·99	+0·35	20	3·1	31
Perth, W. Australia	1018·0	−1·0	70	40	63·4	48·8	56·1	+0·9	52·2	72	6·0	6·73	+0·17	24	5·2	51
Coolgardie	1018·7	−1·2	77	35	61·0	41·3	51·1	−0·1	44·6	79	4·2	1·54	+0·67	10	—	—
Brisbane	1019·1	+0·7	75	40	70·1	46·4	58·3	−0·2	50·4	54	2·2	0·34	−1·86	1	8·6	81
Hobart, Tasmania ..	1010·0	−3·7	58	33	52·7	40·0	46·3	+0·6	41·3	77	6·6	2·80	+0·62	16	4·9	52
Wellington, N.Z. ..	1015·2	+1·3	60	32	52·8	41·7	47·3	+0·9	44·1	85	6·4	2·94	−2·69	18	4·4	46
Suva, Fiji	1014·0	0·0	85	63	78·7	69·7	74·2	+0·8	71·0	85	8·1	7·31	+2·38	18	3·0	27
Apia, Samoa ..	1012·0	+0·1	89	70	86·3	74·4	80·3	+3·1	76·5	80	4·9	8·35	+5·37	23	7·6	67
Kingston, Jamaica ..	1014·7	0·0	95	74	91·5	76·1	83·8	+2·1	75·7	64	4·8	3·62	+2·00	6	8·1	62
Grenada, W. Indies	1014·1	+0·8	86	73	84·9	76·8	80·9	+1·7	77·0	81	7·9	8·22	−1·21	28	—	—
Toronto	1016·3	+1·9	90	50	78·5	61·0	69·7	+0·6	61·5	78	6·0	5·64	+2·80	13	7·2	48
Winnipeg	1013·3	+1·0	93	43	81·7	58·1	69·9	+3·5	59·2	86	5·9	2·94	−0·16	7	10·4	65
St. John, N.B. ..	1014·8	+1·2	80	52	68·7	56·3	62·5	+2·1	59·4	98	8·9	2·09	−1·54	15	4·0	26
Victoria, B.C. ..	1016·6	−0·7	83	43	72·2	51·0	61·6	+1·5	51·8	87	5·5	0·91	+0·49	8	10·2	65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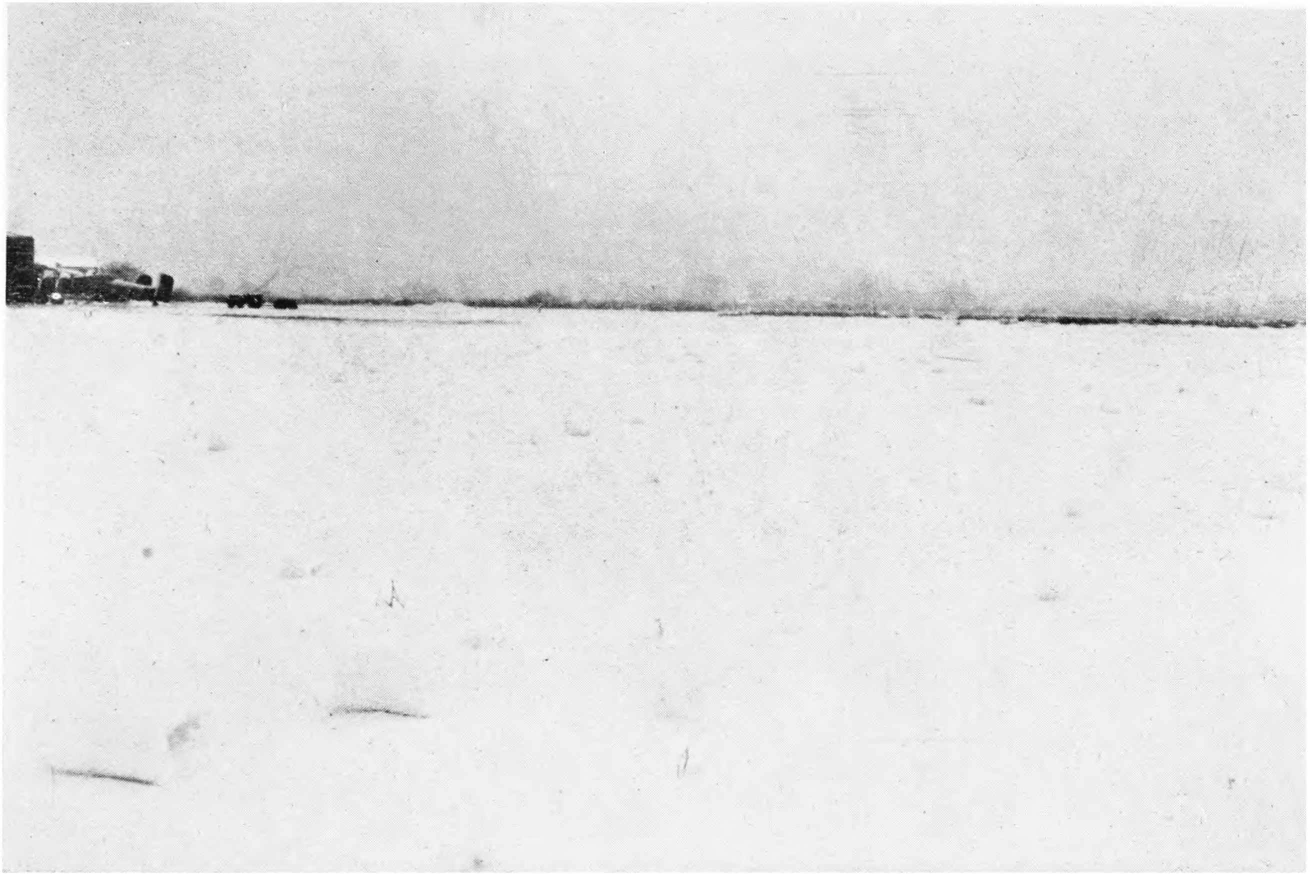
MARK XIV ALTIMETER

(see p. 8)



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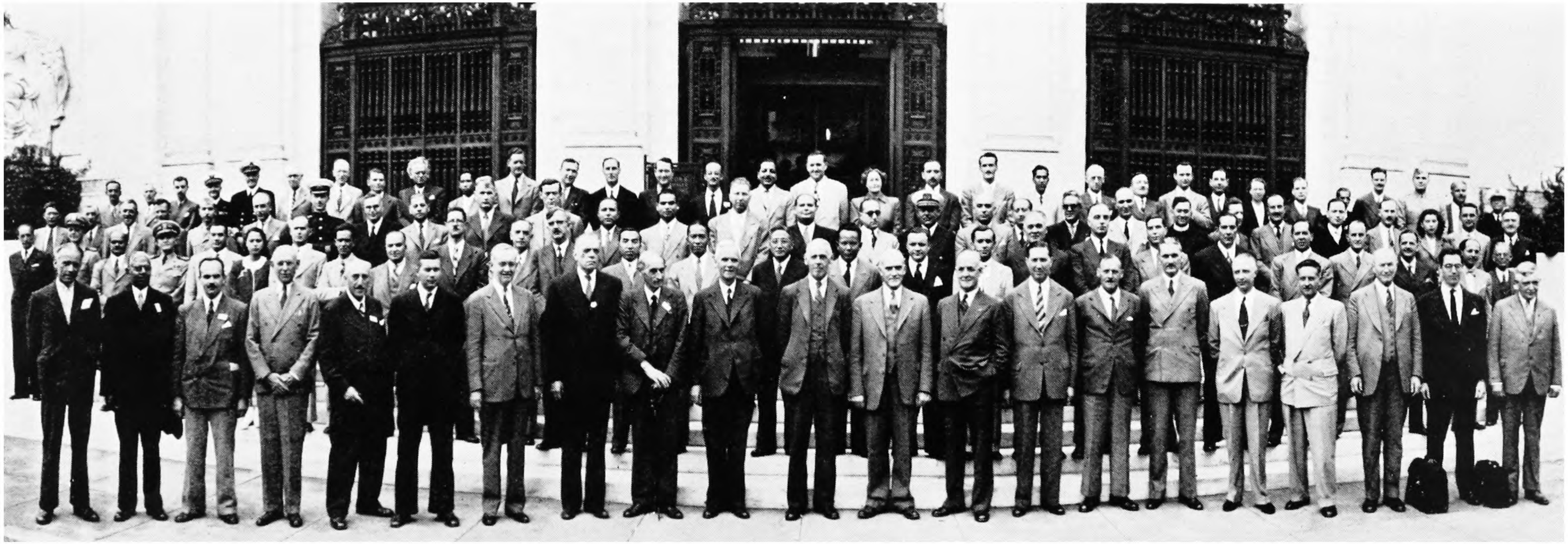
SNOW ROLLERS AT FULL SUTTON, YORKSHIRE, JANUARY 10, 1945
(see p. 19)

Frontispiece]



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INTERNATIONAL METEOROLOGICAL ORGANIZATION—CONFERENCE OF DIRECTORS—WASHINGTON, D.C., U.S.A,

SEPTEMBER 22 TO OCTOBER 11, 1947

M.O. 501 AIR MINISTRY

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THE METEOROLOGICAL MAGAZINE

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THE MEETING OF THE INTERNATIONAL METEOROLOGICAL ORGANIZATION IN TORONTO AND WASHINGTON (*continued*)

AUGUST, SEPTEMBER, OCTOBER 1947

The Climatological Commission (President, Dr. F. X. R de Souza, Brazil; British delegate, Dr. C. E. P. Brooks) met from August 4 to 25, and discussed a wide variety of subjects. The scope of the Commission was defined as climatological investigation of surface and upper air conditions, the application of climatology to other sciences and various forms of human activity (agriculture, aviation, shipping, industry, engineering, medicine, social science, etc.), rules for the computation and publication of climatological data, maintenance of reliability and homogeneity of meteorological observations, and dissemination of climatological data by wireless telegraphy and their possible application to seasonal forecasts.

The Commission was greatly concerned with making the most of the great masses of meteorological observations now being accumulated, and recommended the use of standard cards on which the daily observations would be punched for use in tabulating machines. This process has already been widely used in the United States, and has made possible calculations which would otherwise have been too costly in man hours. A Sub-Commission was appointed to assemble the necessary technical data for surface observations and to design a standard system for international use. For the rapidly growing mass of upper air data, a series of standard cards designed in the British Meteorological Office was accepted as suitable. The possibilities of machine methods were demonstrated to the Commission by representatives of the International Business Machine Company.

Each meteorological service was also asked to issue an annual volume of climatic statistics according to a standard form for permanent reference. For immediate use, e.g. in experimental long-range forecasting, the Commission recommended the resumption of the pre-war arrangement by which monthly mean values for a number of selected stations were broadcast not later than the 5th of the following month. The proposed broadcasts will be in code, and give the station number, the mean pressure, temperature and relative humidity, and the amount of rain. For purpose of comparison normal values are to be included in the first broadcasts, and will also be circulated by post.

The practical use of climatic data was discussed at length, particularly in relation to aviation. In conjunction with I.C.A.O. a standard series of climatological frequency tables was planned to give the best practicable representation of flying conditions at airports.

It was recognised that there is also a wide field for the application of climatology to other human concerns, such as health, agriculture and industry, and a permanent Sub-Commission was formed to develop these applications.

The Commission for Hydrology (Vice-President, Dr. M. Bernard, United States; British delegate, Dr. C. E. P. Brooks) met from August 4–15. The President, Dr. Urivayev of the U.S.S.R., was unable to attend, and Mr. Merrill Bernard was elected Vice-President and took the Chair at all meetings. This was the first meeting of a new Commission, and some time was spent in defining its scope, which was limited to the purely meteorological aspects, the hydrological cycle of precipitation, in evaporation, transpiration, percolation and surface run-off. The hydrological problems of the different countries proved to be very diverse, some countries being preoccupied with questions of water supply and others with forecasting river levels and floods. Among the matters dealt with in resolutions, were co-ordination and exchange of information between countries sharing the same river basin, the standardization of hydrological instruments and methods, and the compilation of a hydrological glossary and international bibliography. Progress was made in the preparation of a multi-lingual dictionary of hydrology.

On August 10 a party of Commonwealth members of the Commission enjoyed a visit to Niagara and the Queenstown Power Station under the able guidance of Mr. C. G. Cline of Canada, who aptly termed himself " the delegate for Niagara Falls ".

The Commission on Agricultural Meteorology (Vice-President, Mr. R. Feige, Palestine; British delegate, Dr. C. E. P. Brooks) met from August 11–23. In the absence of the President, D. V. V. Sinelshikov (U.S.S.R.), Mr. R. Feige (Palestine) was elected Vice-President and presided throughout a very successful meeting. The Commission dealt with phenology, statistical studies of weather and crops, the establishment of networks of " agro-meteorological " stations, long-range forecasts, soil erosion and soil conservation, and also outlined plans for an international journal of agricultural meteorology and for the teaching of agricultural meteorology in agricultural colleges.

Phenological observations are an important part of the data of agricultural meteorology, and suggestions were made for the preparation of an international list and atlas of suitable plants and animals, and the correlation of phenological and crop data. It was also resolved to compare the progress of the various crops at different stages of their growth, obtained by crop and sampling observations, with weather data to establish the minimum requirements of each crop. The Commission recommended the study of advanced statistical methods of analysis in order to make the most of the data so obtained. The meteorological observations required go far beyond the normal practice at crop-weather stations, and include continuous measurements of temperature and of soil humidity. The Commission asked the C.I.M.O. to foster the development of a suitable instrument for measuring soil moisture.

The Commission expressed strong views on the necessity for further research in extended range and seasonal forecasts, which could be expected to yield large economic returns, and it formed a Permanent Sub-Commission to encourage agricultural forecasting of all types.

The teaching of agricultural meteorology should form an essential part of training in agriculture, and the Commission went so far as to prepare abstracts of two suitable courses in the subject, elementary and advanced.

The Commission for Bibliography and Publications (President M. Mezin, France; British delegate, Dr. C. E. P. Brooks) met from September 2–10. This Commission was formed in 1929 to prepare a scheme of subject classification based on the Universal Decimal Classification, but its scope has been enlarged to include all matters concerning publications, resulting in a very long agenda. One of the main tasks of the Commission was to reorganise the world exchange of meteorological information—both observational data and papers on original research. This exchange broke down during the war, and has now to be restarted and extended to include the numerous articles of meteorological interest which appear in scientific and trade journals. The latter are often difficult to trace and obtain, and the Commission recommended the wide extension of a practice developed in Norway, where the meteorological service buys reprints of such papers and distributes them freely to other countries.

An essential means of exchanging information is by bibliographies. The Commission has outlined a proposal that each meteorological service should send lists of all meteorological documents appearing in its country to a central authority, which will at short intervals arrange and duplicate them for sale at a small cost. A basis already exists in the " Bibliographie Signalétique " prepared by the National Meteorological Office of France, and it is hoped that this can be made more complete by international co-operation. It is also hoped to extend the bibliography to include manuscripts, microfilms, motion pictures and catalogues of photographs.

The arrears of the war years received much attention, and the Commission recommended that meteorological services print all important works which appeared in their countries during the war and have not yet been generally issued. If printing is impracticable, microfilm copies should be made for countries requiring them. To this end, each service is urged to arrange facilities for making and reading microfilms. The occupying governments in ex-enemy countries are urged to do the same.

Another major task was the revision of the classification of meteorological literature. The existing classification has served since 1936, but the great extension of knowledge in the past few years, notably in radio technique for the study of the upper atmosphere, has impelled the Commission to draw up a list of proposed revisions and additions. The changes are being submitted to the International Federation for Documentation, and, if accepted, will be incorporated in the Universal Decimal Classification and should come into general use in 1949.

The Commission was also concerned with proposals to publish an international journal of meteorology, possibly in sections each dealing with one branch of the science. Such a journal appears to be especially necessary in the domain of agricultural meteorology (see above). Proposals were also made for the preparation of a glossary of meteorological terms, a multi-lingual dictionary, and a manual for meteorological librarians.

Commission on Projections for Meteorological Charts (President, Mr. I. R. Tannahill, United States; British delegate, Mr. J. Durward). The Commission's main task was to review the decisions taken at its only previous meeting, Salzburg 1937, on account of the greater map areas now needed by meteorological services in connexion with international aviation.

New projections recommended for synoptic charts were:

(*a*) Stereographic projection for the polar regions on a plane cutting the earth at latitude 60°.

(*b*) Conformal conic projections for middle latitudes with standard parallels of 30°, 60° in the northern and 10°, 40° in the southern hemisphere.

(*c*) Mercator projection for the equatorial regions with true scale at latitude $22\frac{1}{2}$°.

It was suggested that in principle the standard projection for climatological charts should be of the equal area type.

Standard scales were recommended for charts ranging from $1 : 40 \times 10^6$ for world charts to $1 : 7{\cdot}5 \times 10^6$ or $1 : 10 \times 10^6$ for charts of a continent. The Commission proposed that charts should be printed in the two colours brown (or ochre) and blue when practicable.

A study of requirements for the location of " sferic " and radar observations resulted in the establishment of a sub-commission to examine the use of a special stereographic or gnomonic projection.

An attempt to find a conformal projection suitable for a world-wide synoptic chart was unsuccessful.

Social and other activities.—The meetings were not all of a scientific nature, our hosts having given much thought and attention to the social side. An official welcome to Canada was given to the delegates by the Dominion Government on August 15, when the Rt. Hon. J. L. Haley, Minister of Justice, received them, while the Deputy Minister of Transport, Cdr. C. P. Edwards, congratulated them on their work and bade them farewell on behalf of the Government at a dinner on September 11. Receptions were also held by the Province of Ontario, and the City and University of Toronto.

Much time was given to the Conference by the Toronto radio stations. Among those who broadcast were Mr. E. Gold and Cdr. C. Frankcom.

Conference of Directors (President, Sir Nelson Johnson). The Technical Commissions finished their work in Toronto on September 15, and a week later the Conference of Directors opened in Washington. The Agenda contained, in addition to the examination of some 400 resolutions submitted by the Technical Commissions, a proposal to form a World Meteorological Convention and another to seek affiliation to the United Nations.

With regard to the Convention, the I.M.O. has hitherto been a semi-official association of Directors of Meteorological Services, but the increased importance of meteorology in a number of directions has led to a widespread belief that the I.M.O. should become an intergovernmental organization which would enhance its status and place it in a more favourable position to enlist official support.

The proposal for a Convention gave rise to protracted discussion, and it was clear that some of the delegates were not without misgivings as to the wisdom of a change in the existing organization. Eventually, after safeguards had been provided to ensure the equality of meteorological services on technical matters, a World Meteorological Convention was drafted and signed by 33 countries. It will come into force on ratification by 30 countries, and the World Meteorological Organization (W.M.O.) will take over the assets and obligations of the I.M.O. which will then cease to exist.

A decision to seek affiliation to the United Nations was quickly reached once the subject of the Convention had been settled. With the assistance of delegates from the United Nations who were present at the Conference, a draft agreement was drawn up which, after approval by a majority of members of the I.M.O., will be submitted to the United Nations. If this is accepted the W.M.O. will be linked with the United Nations as a Specialised Agency.

On the technical side, the Conference approved over 200 resolutions of the Technical Commissions, and took note of about an equal number. Two new Commissions were formed, one to study radio-electric meteorology and the other to deal with problems of arctic and antarctic meteorology. At two sessions, attended by delegates from I.C.A.O., measures were agreed upon to co-ordinate the activities of I.C.A.O. and I.M.O. in meteorological matters.

The Toronto and Washington meetings, considered either separately or as a whole, were most successful, and well repaid the sustained effort that was required from the delegates. Considerable progress was made both on the technical side and in improving the machinery for applying meteorology to human welfare. One of the most important results was, of course, the signing of the international Convention. This decision to effect a fundamental change in the status of the I.M.O. illustrates the determination of members to adapt the I.M.O. to modern world conditions. Another promising feature was the emphasis placed upon research, and at the meetings of the Technical Commissions it was gratifying to notice that the delegates included a high proportion of younger scientists of marked ability and originality of outlook.

NOTES ON THE I.C.A.N. ALTIMETER AND HEIGHT AND AIR SPEED COMPUTER

BY G. A. BULL, B.SC.

Part II

The height and air speed computer is a circular slide rule, shown in the photograph facing p. 48, designed to provide more accurate values of the height and air speed of an aircraft than those read directly off the altimeter and air speed indicator. It is not intended for use above 30,000 ft. The Mark IIA type is arranged to correct the indicated air temperature for adiabatic temperature rise due to the speed of the aircraft.

The computer gives an improved value of height from the indicated height, the temperature of the air, and the subscale setting of pressure.

The computer is designed approximately on the assumption of temperature increasing downwards from the aircraft at the rate of 1·98°C./1,000 ft. but only satisfies this assumption exactly if the ground pressure is 1013·2 mb. The computer takes no account of the variation of gravity with height or latitude.

Notation.

H_i = height indicated by altimeter in thousands of feet
H_c = corrected height given by computer
H_c' = corrected height on assumption of I.C.A.N. lapse rate between aircraft and ground
H_t = true height of aircraft
T_H = absolute temperature at aircraft levels as read by aircraft thermometer
P_H = pressure at aircraft level (mb.)
P_G = ground pressure set on subscale
T_G = ground temperature
P_0 = 1013·2 mb.
T_0 = 288°A.
l = 1·98°C./1000 ft.
n = $g/lR = 5{\cdot}256$

Then from equation (3) (Part I) we have

$$H_i = \frac{T_0}{l}\left\{\left(\frac{P_G}{P_0}\right)^{1/n} - \left(\frac{P_H}{P_0}\right)^{1/n}\right\}. \qquad \ldots (7)$$

The differential equation for the variation of pressure with height is

$$\frac{dP}{P} = -\frac{nldz}{T_H + lH_c' - lz}, \qquad . \; (8)$$

where z = height, since T_H = temperature at height H_c'

Integrating this equation,

$$\left(\frac{P_G}{P_H}\right)^{1/n} = \frac{T_H + lH_c'}{T_H}. \qquad \ldots (9)$$

From (7) and (9), equating values of $(P_H/P_G)^{1/n}$ we have

$$\frac{T_H}{lH_c'} = \frac{T_0\left\{1 - \dfrac{lH_i}{T_0}\left(\dfrac{P_0}{P_G}\right)^{1/n}\right\}}{lH_i\left(\dfrac{P_0}{P_G}\right)^{1/n}}, \qquad \ldots (10)$$

whence, taking logarithms to base 10,

$$\log H_c' = \log H_i + \frac{1}{n}\log P_0 - \frac{1}{n}\log P_G - \log\left\{T_0 - lH_i\left(\frac{P_0}{P_G}\right)^{1/n}\right\} + \log T_H. \; .(11)$$

The computer is, however, based on the formula*

$$\log H_c = \log H_i + \frac{1}{n}\log P_0 - \frac{1}{n}\log P_G - \log\left\{T_0 - lH_i\right\} + \log T_H \qquad \ldots (12)$$

The two formulae differ only in the term $(P_0/P_G)^{1/n}$ multiplying H_i. This does not have much effect so that H_c is nearly equal to H_c'.

To see what difference there is, note that

$$\frac{H_c}{H_c'} = \frac{lH_i}{T_0 - lH_i}\left\{1 - \left(\frac{P_0}{P_G}\right)^{1/n}\right\} \qquad \ldots (13)$$

---

* This formula is given in the relevant Air Ministry instructions.

so that, to the first order in $(P_0 - P_G)/P_0$

$$H_c' - H_c = \frac{lH_i^2}{T_0 - lH_i} \cdot \frac{P_0 - P_G}{nP_0} \qquad .. (14)$$

Even if P_G is as low as 950 mb. the difference between H_c' and H_c is only 10 ft. at 10,000 ft. and 90 ft. at 30,000 ft.

We now consider the errors in H_c due to the actual atmosphere below the aircraft not having I.C.A.N. lapse rate. If the harmonic mean temperature between aircraft and ground is greater in the real atmosphere than in one with I.C.A.N. lapse rate then the computer will give a height less than the true height and conversely. The error will be greatest in magnitude and positive in sign when there is an inversion. A lapse rate greater than the I.C.A.N. value gives a negative error but since the lapse rate can never greatly exceed the I.C.A.N. value large negative errors will not occur.

If the real atmosphere has a lapse rate λ the relation between H_c' and H_t is

$$\left.\begin{aligned} &\left(\frac{T_H}{T_H + lH_c'}\right)^{1/l} = \left(\frac{T_H}{T_H + \lambda H_t}\right)^{1/\lambda} \\ \text{or } &\left(1 + \frac{lH_c}{T_H}\right)^{1/l} = e^{H_c/T_H} \text{ if } \lambda = 0 \end{aligned}\right\} \qquad .. (15)$$

Numerical values for atmospheres of constant lapse rate are easily deduced from formulae (15).

Thus if the real atmosphere has an inversion of 1°C./1,000 ft., such as may reasonably happen in winter over several thousand feet, the error

$$H_c' - H_t = 3H_t^2/2T_H,$$

terms of order H_t^3/T_H^2 and less being neglected.

At 5,000 ft. for $T_G = 270°$A. the error is + 140 ft.

If the real atmosphere has a dry abiabatic lapse rate the error

$H_c' = H_t = -\frac{1}{2}H_t^2/T_h$ neglecting terms of order H_t^3/T_H^2 and higher, so that at 10,000 ft. the error would be − 210 ft. if $T_G = 270°$A.

Further tests using the computer itself to find H_c were made with the 5-year means of January and July temperatures over Mildenhall, a measurement of upper air temperature taken through an intense winter inversion and finally with a record taken at Madras on a day of thunderstorms during the SW. monsoon. The values found are set out in Table V. It is assumed that T_H as read by the aircraft thermometer is the true temperature at aircraft level. The error in H_c due to an error δT_H is easily seen to be $H_c \delta T_H / T_H$. For example, at 30,000 ft. T_H is about 230°A. giving an error of 130ft. for every degree error in T_H.

It will be seen that a very considerable improvement in knowledge of height is obtained at high levels by using the computer, while the association of positive errors in the corrected height with inversion or small lapse rate and negative errors with steep lapse rates is clear.

The change in sign of the error in corrected height from positive to negative at high levels in two of the ascents is a reflection of the increase in lapse rate with height.

TABLE V—INDICATED AND COMPUTED HEIGHTS

Pressure P_H	Temp-perature T_h	True height H_t	Height indicated by altimeter H_i	Error in indicated height	Corrected height H_c	Error in corrected height
mb.	°C.	ft.	ft.	ft.	ft.	ft.
Mildenhall (5-year means in January)						
1000		0	0	0	0	0
900	0	2,780	2,877	+ 97	2,800	+ 20
800	− 4	5,850	6,027	+ 177	5,900	+ 50
700	− 9	9,270	9,507	+ 237	9,400	+130
600	−16	13,130	13,429	+ 299	13,245	+115
500	−25	17,560	17,915	+ 355	17,720	+160
400	−37	22,760	23,208	+ 448	22,800	+ 40
Mildenhall (5-year means in July)						
1000		0	0	0	0	0
900	11	2,900	2,877	− 23	2,900	0
800	5	6,080	6,027	− 53	6,110	+ 30
700	0	9,620	9,507	− 113	9,750	+130
600	− 7	13,620	13,429	− 191	13,800	+180
500	−16	18,210	17,915	− 295	18,250	+ 40
400	−26	23,620	23,208	− 412	23,500	−120
Hanover (January 31, 1947)						
1013	−12	0	0	0	0	0
1000	−12	320	363	+ 43	330	+ 10
900	− 7	3,000	3,240	+ 240	3,080	+ 80
882	− 3					
800	− 5	6,030	6,390	+ 360	6,250	+220
700	−12	9,430	9,876	+ 446	9,650	+220
600	−21	13,240	13,792	+ 552	13,400	+160
500	−29	17,580	18,278	+ 698	17,800	+220
400	−43	22,640	23,571	+ 931	22,570	− 70
300	−57	28,760	30,059	+1,299	28,500	−260
Madras (August 20, 1947)						
1000	30	0	0	0	0	0
900	26	3,050	2,877	− 173	3,060	+ 10
800	18	6,390	6,027	− 363	6,380	− 10
700	10	10,070	9,507	− 563	10,020	− 50
600	4	14,220	13,429	− 791	14,200	− 20
500	− 6	18,990	17,915	−1,075	19,000	+ 10
400	−18	24,500	23,208	−1,292	24,550	− 40
300	−34	31,410	29,696	−1,714	31,000	−410

Note.—The true heights were computed from the tephigram. No corrections have been applied for variation of gravity with height. The value of g used in constructing the tephigram is the same as that used in the I.C.A.N. atmosphere so that the errors in the indicated and computed heights are unaffected by ignoring the gravity correction.

The sign of the error in the indicated height is less directly associated with lapse rate. High positive errors in indicated heights are associated with temperatures lower than standard for the height and conversely.

Air speed computer.—The air speed computer gives an improved value of air speed using the same scales as the height computer.

If V_c is the corrected air speed V_i the speed shown by the air speed indicator, ρ the air density at aircraft level, and ρ_0 the density at 1013·2 mb. and 288°A., then

$$\rho_0 V_i^2 = \rho V_i^2, \qquad \text{..(16)}$$

so that $$\frac{P_0}{T_0} V_i^2 = \frac{P_H}{T_H} V_c^2,$$

whence $$V_c^2 = \frac{T_H P_0 V_i^2}{T_0 P_G \left\{1 - \frac{lH_i}{T_0}\left(\frac{P_0}{P_G}\right)^{1/n}\right\}^n}, \qquad \ldots (17)$$

whence taking logarithms and neglecting the difference between 1 and $(P_0/P_G)^{1/n}$ we have

$$\log V_c = \log V_i + \tfrac{1}{2} \log T_H - 2{\cdot}628 \log (288 - 1{\cdot}98\, H_i) - \tfrac{1}{2} \log P_G + 6{\cdot}7364 \qquad \ldots (18)$$

$$\text{since } \tfrac{1}{2} \log 1013{\cdot}2 + 2{\cdot}628 = 6{\cdot}7364$$

This is the formula which the instrument applies*.

No error due to the real atmosphere differing from the I.C.A.N. one can occur since the velocity depends only on pressure and temperature at aircraft level. The error is due solely to putting $(P_0/P_G)^{1/n} = 1$ and the percentage error due to this is

$$\frac{100lH_i}{T_0 - lH_i} \cdot \frac{P_0 - P_G}{nP_0}$$

which is less than ½ per cent. even at 30,000 ft. with a subscale setting of 950 mb.

NOTE ON SOME CASES OF AIRCRAFT ICING

BY JACQUES COCHEMÉ, B.SC.

Introduction.—During certain operational trials carried out by Transport Command Development Unit, R.A.F., in a York aircraft, a meteorological air observer was included in the crew. The facilities for making observations on these trials were exceptionally good; the meteorological observer had more time than usual for observation as opposed to log keeping and computation, and, in the York, the wind screen of the pilot's cockpit (the meteorological air observer sat in the second pilot's seat) is so shaped that many particles hit it fairly squarely. It is therefore an exceptionally good "observation place".

Observations.—The data collected during 21 relevant occasions or runs are given in the table on pages 34 and 35. With the exception of run 12, which was below cloud base, all these runs were carried out in cloud at the flying heights stated. Most temperatures were taken in clear air before entering cloud as the penetrations were of short duration and the observer's attention was concentrated on other items during that time.

The entries in the column headed "Particles observed" refer to types identified with fair certainty. They are not intended to constitute an exclusive list of the kinds of particles present in each cloud. By globular snow is meant a rounded particle, opaque and densely white, which appeared to be tightly packed. Snow flakes, on the other hand, presented the usual feathery appearance. Water drops appeared as transparent discs on the wind screen (beyond a certain size, not met during the runs, the discs are "starred"). In the case of relatively small drops detection was only possible in the corners of the screen after a layer the thickness of several particles had accumulated. Fine ice crystals were identified as a powdery deposit on the corners of the screen but

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* See relevant Air Ministry instructions.

Run	Date	Locality	Cloud type	Flying height	Pressure	Temperature
				ft.	mb.	°F.
1	9.1.47	Scilly	Cb with large anvil, 5,000 ft. tall. Dissolving cloud thin at the waist. Base: 3,000 ft., top: 14,000 ft.	9,000	—	7 (clear air)
2	9.1.47	Scilly	Cb, more active, with anvil 2,000 ft. globular up to the anvil. Base: 2,500 ft., top: 13,000 ft.	9,000	—	—
3	9.1.47	Scilly	Young, well rounded, globular cumulus, developing	6,000	—	18 (clear air)
4	9.1.47	Scilly	Same as in run 2	5,000	—	22 (clear air)
5	13.1.47	Bristol Channel . .	Cb with large sprawling base and anvil. Base: 2,500 ft., top: 18,000 ft.	11,000	—	1 (clear air)
6	13.1.47	Gower Peninsula . .	Cb with large sprawling base, heavy central column with anvil. Base: 3,000 ft., top: 18,000 ft.	9,000	—	4 (clear air)
7	13.1.47	Gower Peninsula	Same as in run 6	4,000	—	24 (clear air)
8	17.1.47	Isle of Man . .	Sc, base: 4,000 ft., top: 6,000 ft. No rain below	5,400	835	22 (clear air)
9	17.1.47	Belfast	Sc layer with Cu tops, possibly orographic. Rain in patches below. Base: 2,500 ft., tops: 6,000 ft. and 7,500 ft.	5,600	825	18 (clear air)
10	17.1.47	Tiree	Cb, base: 2,500 ft., top: 15,000 ft.	10,000	700	5 (clear air)
11	17.1.47	Barra	Cb, base: 2,500 ft., top: 17,000 ft., anvil: 2,000 ft. in height	15,700	555	−19 (clear air)
12	24.1.47	off Essex	Cu giving snow showers. Base: 1,500 ft., top: 7,000 ft.	1,100	990	25 (in shower)
13	24.1.47	52° 30′ N. 3° 00′ E.	As in run 12	6,000	830	6 (clear air)
14	24.1.47	52° 30′ N. 3° 00′ E.	As in run 12	4,500	880	11 (clear air)
15	24.1.47	52° 30′ N. 3° 00′ E.	As in run 12	3,000	930	16 (clear air)
16	31.1.47	Massif Central 48° 50′ N. 1° 11′ W.	Ac, base: 11,000 ft., top: 16,000 ft.	14,500	575	−16 (in cloud)
17	18.3.47	Pembroke . .	Cb, base: 2,500 ft., top: 15,000 ft. End of a row	—	750– 715	16 (clear air) 16 (in cloud)
18	18.3.47	Pembroke . .	Cb, base: 3,000 ft., top: 14,000 ft.	8,500	740	16 (clear air)
19	18.3.47	Pembroke . .	As in run 18	6,000	800	26 (in cloud)
20	18.3.47	Cork	Cb with large sprawling base. Base: 2,000 ft., top: 15,000 ft.	—	—	19 (clear air)
21	18.3.47	Cork	As in run 20	7,100	770	22 (clear air)

Air-speed	Time in cloud	Particles observed	Type of icing	Rate of icing	Turbulence
kt.	min.				
175	½ 1	Fine globular snow	Fine grained snow pack	Slow	Continuous 2
—	½	Globular snow ..	Snow conglomerate or pack	Moderate	Continuous 4
170	½	Supercooled water droplets	Clear granular ..	Moderate	Continuous 2
170	½	Snow larger than in run 2	Snow pack	Rapid	Continuous 5
160	½	Snow, globular about ⅛-in. diameter	Opaque snow pack	Rapid	Continuous 3
170	1	Snow, about $\frac{3}{16}$-in. diameter	Opaque snow pack	Moderate	Continuous 2
170	1 1	Rain drops Snow flakes	Clear granular No record	Rapid	Continuous 3
170	2½	Small water drops ..	Fine clear granular	Slow	Continuous 2
160	2	Small water drops ..	Clear granular ..	Moderate	Continuous 2
170	2	Fine ice crystals ..	None	—	Continuous 2
160	2	Fine ice crystals ..	None	—	Continuous 1
180	1½	Large snow flakes ..	None	—	Continuous 2
190	2	Snow	Opaque snow pack	Rapid	Continuous 3
180	2	Snow	Opaque snow pack	Rapid	Continuous 3
170	2	Large snow.. ..	Opaque snow pack	Rapid	Continuous 4
160	10	Snow, about ⅛-in. diameter	Opaque snow pack	Moderate	Continuous 2
150 155	4	Supercooled drops ..	Semi-opaque fine granular	—	—
150	3	Fine snow, water drops near end of run	At end of run: clear fine granular	Slow	Continuous 2
160	3	Fine snow	Snow pack	Slow	Continuous 2
160	4	Fine snow	Semi-clear fine snow pack	Slow	Continuous 4
160	6	Fine snow	Semi-opaque granular snow pack	Moderate	Continuous 3

mainly on the " Rebecca " aerial, a thin antenna, painted black, sticking out of the side of the aircraft, and against which the particles were pressed for a fraction of a second and seen, invariably, as aggregates of rods. Two more types of particles may have been present but much uncertainty remains attached to their observation. The first, suspected during runs 9, 20 and 21, resembled frozen drizzle, the difference between it and a water drop being an apparently less plastic behaviour on impact. The second consisted of a snow flake to which water was adhering either in the form of drops or as a film. Its presence was suspected during runs 4, 5, 13, 14 and 16. The impression was gained that, at the flying heights stated in those runs, the clouds were " mixed clouds ", i.e. contained both water and ice, either separately or actually united.

Turbulence is expressed in an arbitrary scale where 10 represents most severe or disastrous bumpiness.

Discussion. *No icing in dry clouds.* (Runs 10 and 11).—Run 11 is a typical case of absence of icing in ice cirrus, cumulogenitus or not, at low temperatures. The cloud is dry and the particles left in it are small and can penetrate an aircraft as sand does a house during a sandstorm, but they do not adhere to its outside surface.

The absence of icing in run 10 is a rare and most interesting observation. The mechanism is thought to have been the same as for run 11, but the level, both absolutely and as a fraction of the total height of the cloud, is relatively low, and the temperature relatively high for ice accretion not to take place. This becomes more obvious if one compares run 10 with, for instance, run 6, where under similar conditions of height and temperature icing was readily deposited. The cloud of run 10 was dissolving and there was probably no ascending current at the flying height. Large particles had sunk below it and wet particles disappeared, giving a relatively tall anvil with a thin waist and unusually good visibility inside it. The flying height corresponded to the waist of the anvil.

In the writer's experience flying in cirrus cumulogenitus or anvils is a safe procedure with respect to icing; but the cloud must have characteristic tenuous anvil structure and be well above cauliflower-shaped convective masses. Carburettor icing, however, with engines which are prone to it, will take place in this type of cloud if the temperature is sufficiently low and the carburettor and intake heating left switched on, since the heat provided is then just sufficient to make the ice crystals sticky.

Icing in water clouds. (Runs 3, 8, 9, and 17).—Runs 8 and 9 are text-book cases in all respects, even as regards temperature. Clear granular ice of fine grain was obtained. A thick deposit would have been opaque, though not white, like accretion due to fine granular snow of the same size of particle. In both cases the drops were small, less than 1-mm. diameter. Such icing is only dangerous if it is allowed to accumulate for a long time, as might happen at night if the layer is continuous and no change in level effected.

It is interesting to compare the cloud of run 3 with an older convection cloud which was adjacent to it, that of runs 2 and 4. At 6,000 ft. and 18°F. there appeared to be nothing but water droplets in the cloud of run 3.

Icing in mixed cloud. (Runs 1, 2, 4–7, 13–16, 18–21).—14 out of the 18 cases of icing listed are attributed to snow. But for snow to adhere to an aircraft, " cement " is necessary in the form of water. This is well shown in runs 12 to 15.

On the day of these runs, during the cold spell of 1947, a layer of cold unstable air some 7,000 ft. thick was moving across the North Sea, from **east** to west. After a few miles of sea track that air filled with convective clouds giving snow showers. One of these was crossed at three different heights (runs 13–15), and in each case the snow began to accumulate on the wind screen, spinners and leading edges. The previous run (12) had been below cloud and in snow, and no accretion had taken place at a temperature of 25°F. It is assumed that the difference between run No. 12 and the other three is that there was water as well as snow in the rising air in cloud and that it was a mixture of the two which caused icing. Below cloud, on the other hand, the snow flakes were descending and dry and could not stick to the aircraft. Convection appeared to be moderately active in the cloud.

Nevertheless flying in a cloud containing snow particles does not always imply that icing will form. The following occasion, which is not listed, illustrates this point: on the very cold morning of January 31, 1947, the crew were at Lyneham waiting to take off for Malta. Snow showers were occurring about twice an hour. We took off after a shower, climbed on track and the following temperatures and cloud formations were observed:—

Pressure (mb.)	990 (surface)	975	950	900	850	800	750	720
Temperature (°F.)	25	26·4	25·2	21·0	16·8	11·6	6·4	2·0

Cloud:—10 tenths stratus, 2,000–2,800 ft., 925–900 mb.
8 tenths stratus, 875–860 mb.
1 tenth cumulus tops to 700 mb.
2 tenths altocumulus, 750–700 mb.

The cumulus and altocumulus were avoided. No icing was experienced whilst crossing the stratus layers although there were some snow flakes in them. It would appear that the fine particles in the stratus were either too small to cause icing or that they were already frozen. That they were too small could be attributed to the fact that there was no convection to feed them and that the presence of the snow flakes would tend to reduce them to their smallest possible size under the existing conditions, owing to differences in vapour pressure.

Further south, another very interesting run took place that day, run 16. The temperature at the base of the cloud of this run must have been about −4°F.; nevertheless, for ice accretion to take place at the rate observed, it must be supposed that there was supercooled water in it as well as snow. There was also some convection as evidenced by the turbulence. This was the run during which the presence of snow flakes with water adhering to them was most strongly suspected.

Conclusions.—It is suggested that icing in convection clouds containing snow is a common occurrence, because a mixture of snow and water is also a common occurrence over a wide temperature range below freezing. It is thought that this mixture may even be found with water and snow in actual contact with each other. That such conditions should readily give rise to icing is obvious. The water and snow are comparable to mortar and bricks and the accretion can be rapid since much of the latent heat of crystallization has already been given off.

It is suggested that this type of icing predominates increasingly in frequency and importance as the temperature decreases down to the very low temperatures at which icing is now known to occur.

This ice accretion of the snow-pack type occurring in mixed clouds must, together with its attendant circumstances, be given its proper place amongst the various kinds of icing now that flying takes place over a far greater range of height, temperature, and cloud conditions.

In order to interpret and reconcile the foregoing observations it is suggested that for the production of supercooled water, necessary to give rise to ice accretion either alone or mixed with ice crystals, not only must the temperature be in the right range but the rate of cooling by ascent in the cloud must exceed a critical value which itself varies with the temperature. It appears probable in fact that the formation and size as well as the suspension of supercooled water drops in cloud depend on the rate of cooling by ascent. This state of water would be ephemeral, especially at very low temperatures, and would not endure in the absence of sufficient convection. This suggestion implies an intimate relationship between convection in clouds, due either to steady updraughts or cellular activity, and most kinds of ice accretion.

LONDON MATHEMATICAL SOCIETY

On Thursday December 18, 1947, Mr. G. K. Batchelor gave a lecture to the London Mathematical Society entitled " Progress and difficulties in the theory of isotropic turbulence ".

Atmospheric turbulence plays an important part in many meteorological processes and its elucidation is of material interest to the meteorologist. However, turbulence in the atmosphere is undoubtedly still more complex than the isotropic turbulence in an incompressible fluid discussed by Mr. Batchelor. In the latter the mean velocity over a long period is zero (or uniform) at all points, and the averaged properties of the motion have spherical symmetry.

Mr. Batchelor explained that the fundamental problem of turbulence theory was to derive the statistical characteristics of the turbulent motion from the equations of motion of a viscous fluid and the equation of continuity. We could not hope to specify the detail of the motion, but we might expect that some statistical characteristics would become independent of the initial conditions (e.g. the correlation between velocities at pairs of points).

Mr. Batchelor first discussed turbulent motion under conditions in which the quadratic terms of the equations of motion can be neglected. A solution was obtainable which gave the rate of decay of turbulent energy as inversely proportional to $t^{5/2}$ ($t =$ time); and also gave solutions for other statistical properties. Such conditions of turbulence occur in the final stages of dissipation of turbulent energy and theoretical deductions are well verified by experiment.

Mr. Batchelor then turned to the more general turbulent conditions in which the quadratic terms cannot be neglected and for which no complete theoretical solution had yet been obtained. However, certain statistical relationships were deducible from the equations of motion, and had been verified by wind-tunnel experiments on isotropic turbulence. This fact gave confidence that the equations of motion for a viscous fluid were in fact applicable to such turbulence. Various other fundamental statistical relationships appeared from wind tunnel experiments; in particular the turbulent energy decayed inversely as the time during the initial stages when the quadratic terms played a significant part in the equations of motion. The theoretical explanation of this was the subject of current research.

In conclusion Mr. Batchelor discussed the distribution of turbulent energy among eddies of various sizes and in particular the energy relations of the small-scale eddies which are simultaneously present with the larger ones and the behaviour of which has many interesting properties.

J. S. SAWYER

LETTER TO THE EDITOR

Hypostereograms

Mr. Tricker's hypostereograms, reproduced in the August 1947 issue of the *Meteorological Magazine* are of much interest, but there is a point regarding their interpretation which calls for mention. The stereoscopic effect depends upon relative horizontal displacements between corresponding points in the left and right images. In an ordinary stereogram in which the two images are produced simultaneously by two cameras separated by a fixed or variable horizontal distance the displacement is inversely proportional to the distance from the cameras, and a faithful representation of the distribution in space of the different objects in the picture is obtained when the pictures are viewed in a stereoscope.

In stereograms produced by Mr. Tricker's method, in which the displacement is produced by tranverse movement of the object between the two exposures, the displacement is proportional to the velocity and inversely proportional to the distance. Thus a faithful representation will not be obtained unless the velocity v of all objects appearing in the picture is the same. For all objects forming part of the landscape, v is zero. Consequently there is no displacement and the landscape appears " at the back of everything ", as Mr. Tricker points out. If the wind increases with height, the higher clouds will apparently be brought nearer to the viewer and *vice versa*. The stereoscopic representation of skyscapes in which there are clouds at different levels is therefore liable to be considerably distorted, and the stereograms cannot be expected to give anything more than a broad qualitative idea of the three-dimensional distribution.

E. G. BILHAM

January 8, 1948

NOTES AND NEWS

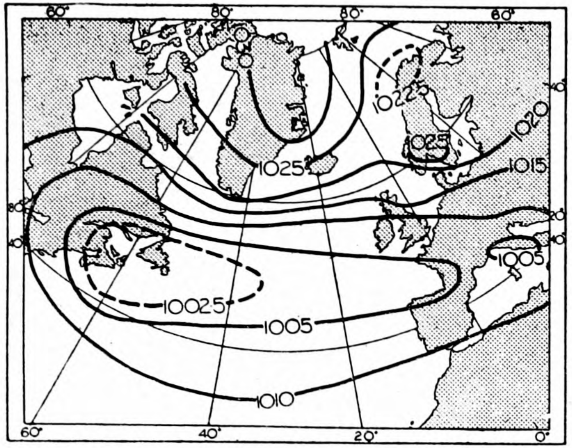
The year 1947 provided the greatest variety of abnormal weather over the British Isles since regular observations began. The severity of the latter part of the winter 1946–7, the rain and floods of March, and the drought and warmth of late summer and autumn, were all unprecedented for a very long period. The year also included the two longest spells of continuous easterly wind for at least 66 years, one giving severe winter weather and the other the warmth and sunshine of August. The weather has been discussed briefly month by month in the *Meteorological Magazine*, and the character of the winter was described in two articles in the issues for March and April. From the latter discussion it appears that in this country the winter of 1946–7 was by far the most severe in Great Britain since at least 1881, while in Holland it was probably the most severe since that of 1788–9. The April issue included a map of the deviations of mean pressure from normal in February 1947, which shows a great excess of pressure (exceeding 25 mb.) north-west of Iceland, and a deficit of 10–15 mb. over the eastern Atlantic in 40–50°N. The chart of actual pressures (reproduced here as Fig. 1) showed a decrease from 1035 mb. in north-east Greenland to 1002 mb. in mid Atlantic (latitude 50°N.) associated with the persistent strong easterly winds. An upper anticyclone extended northwards simultaneously with the surface anticyclone but was further to the west; after February 4 the upper winds were mainly westerly though weaker than usual. Broadly speaking, the belt of strong upper westerlies was displaced southward, associated with the large temperature deficiency over the British Isles and adjacent part of Europe.

The chart of deviations for March is rather similar, but the area of deficient pressure has spread over the British Isles. Fig. 2 shows the actual pressures; the area below 1000 mb. from Ireland westwards marks the scene of great cyclonic activity, which gave rise to heavy snow in the first half of March, and rain in the second half. This was the wettest March in England since 1747, and the rain and melting snow combined to cause disastrous floods.

In April (Fig. 3) the normal type of south-westerly circulation returned but with unusual intensity, pressure being 10 mb. below normal north of Iceland and 10 mb. above normal on the Riviera. There was much deep cold air over the Atlantic and occasionally over the British Isles; upper air pressure and temperature were well below average. A series of deep depressions travelled eastwards or north-eastwards across the British Isles or between Iceland and Scotland; these and the associated SW. winds brought Scotland the wettest April since before 1869.

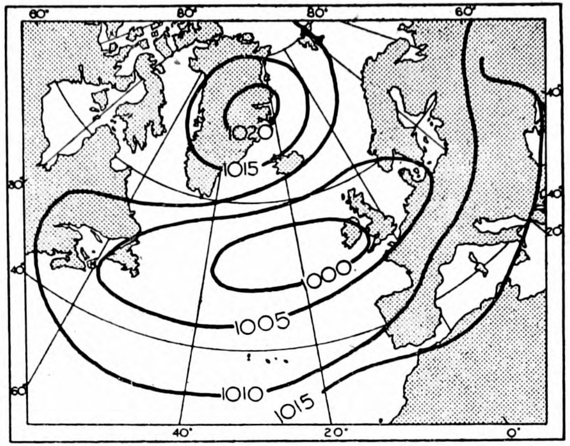
The weather of May, June and July was not remarkably abnormal, though pressure continued low over the Atlantic and northern Ireland had heavy rain, especially in May and June. There was an excess of southerly winds at all heights with a corresponding excess of temperature. The record-breaking heat on the continent in late June and late July was associated with high upper air pressure. August however brought more NE. winds, abnormal heat and drought. The period August 9 to September 2 was unique in the persistence of high pressure over north-west Europe and E.–NE. winds over a large part of south-east England, unbroken except for local land and sea breezes on the south coast. Fig. 4*a* shows the mean pressure at M.S.L. during this period, and Fig. 4*b* shows the height of the 300 mb. isobaric surface in feet. A high level of this surface represents an anticyclone in the upper air. Fig. 4*b* is based partly on direct observations and partly on interpolated values. The upper winds over the British Isles were unusually light for a longer period than any previously known since observations began in 1940. The surface air over this country was not especially dry, owing to moisture from the North Sea, which resulted in much morning fog and stratus in eastern and northern districts, but the usual anticyclonic subsidence led to mainly dry stable conditions aloft, only broken during a thunderstorm in London on August 23.

A high pressure in the upper troposphere and the corresponding high and cold stratosphere is a necessary condition for a persistent anticyclone, but it is not in itself sufficient. The dynamics and thermodynamics of the troposphere



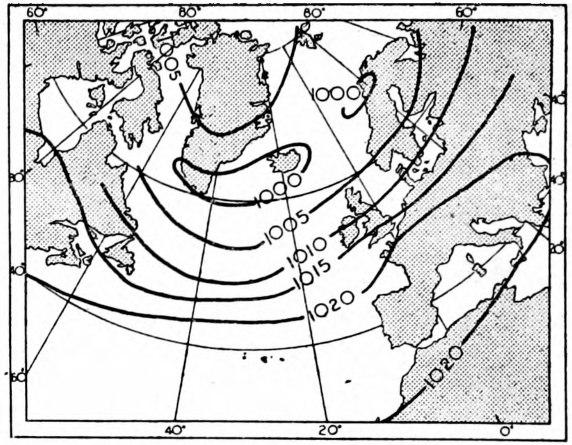
60°
80°
80°
60°
1022.5
1025
1020
1015
1005
10025
1005
1010
60°
40°
20°
0°

FIG. I—MONTHLY MEAN PRESSURE, FEBRUARY 1947



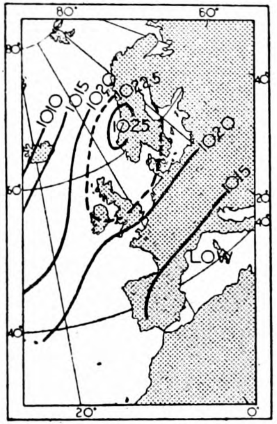
60°
80°
80°
60°
1020
1015
1000
1005
1010
1015
40°
20°
0°

FIG. 2—MONTHLY MEAN PRESSURE, MARCH 1947



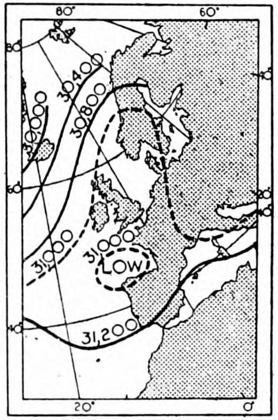
60°
80°
80°
60°
1005
1000
1000
1005
1010
1015
1020
1020
40°
20°
0°

FIG. 3—MONTHLY MEAN PRESSURE, APRIL 1947



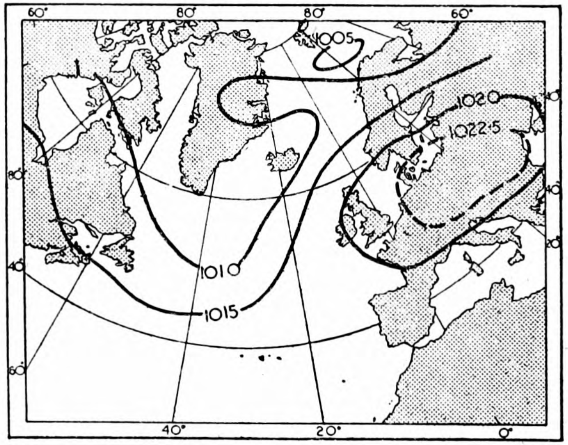
80°
60°
1010
1015
1020
1022.5
1025
1020
1015
LOW
20°
0°

FIG 4*a*—MEAN PRESSURE AT M.S.L., AUGUST 9—SEPTEMBER 2, 1947



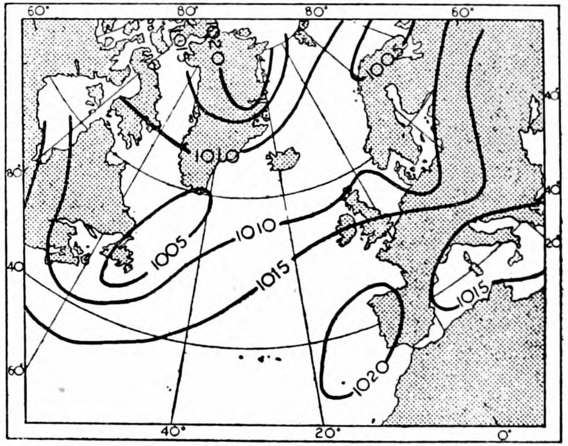
80°
60°
30,400
30,600
30,800
31,000
31,000
LOW
31,200
20°
0°

FIG. 4*b*—MEAN HEIGHT OF 300 MB., SURFACE, AUGUST 9—SEPTEMBER 2, 1947



60°
80°
80°
60°
1005
1020
1022.5
1010
1015
40°
20°
0°

FIG. 5—MONTHLY MEAN PRESSURE, OCTOBER 1947



60°
80°
80°
60°
1015
1020
1005
1010
1005
1010
1015
1015
1020
40°
20°
0°

FIG. 6—MONTHLY MEAN PRESSURE, DECEMBER 1947

are certainly of great importance, and more especially the conditions associated with the successive regenerations normally accompanied by the rapid subsidence of fresh masses of polar air. These processes are a kind of mutual interaction between the anticyclone system and the surrounding conditions.

A feature of the period was the steep upper gradient over Canada. Depressions moved quickly eastward across Canada into the Atlantic and then turned north-east up the Denmark Strait. Deep cold air never penetrated east of longitude 30°W. It is the advance of deep cold air and the associated upper trough which is liable to lead to the collapse of a warm anticyclone.

The conditions in the autumn resembled those of 1921; in that year conditions were anticyclonic until November 12 and there was no wet spell in south-east England until January 1922. Another feature which has often been noted in previous dry spells was much in evidence this autumn, namely the light rainfall in a variety of synoptic situations, any one of which could easily have given much more rain. The most remarkable month was October (Fig. 5) when an anticyclone covered central and western Europe, in late October the anticyclone at the 300 mb. level lay over Scandinavia. Over England and Wales this was the driest October, probably since 1809, but Scotland lay partly outside the influence of the anticyclone and the month was not as dry as October 1946. September and November were also dry over England and Wales. The anticyclones of September to November were of a normal type, the exceptional feature being their frequency. They mostly developed close to the British Isles.

Anticyclonic conditions returned in December (Fig. 6) when pressure was high from Spain to the north of Scotland (see p. 45). This month was the seventh consecutive dry month in England and Wales.

For the year as a whole the temperature, rainfall and sunshine differed little from normal. The following table shows the general character of the weather:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	94	−6	+0·4	93	−19	99	33
Scotland	87	−6	0·0	97	−21	102	29
Northern Ireland . .	83	5	+0·3	105	−21	96	29

C. E. P. BROOKS.

First Director of Radio Research

The Lord President of the Council has approved the promotion of Dr. R. L. Smith-Rose, D.Sc., Ph.D., M.I.E.E., to the new post of Director of Radio Research in the Department of Scientific and Industrial Research (D.S.I.R.). Dr. Smith-Rose will be in charge of the radio research work of the Department for which a new station will eventually be established. The new station will incorporate the work now being carried out in the Radio Division of the National Physical Laboratory, and the Radio Research Station (D.S.I.R.) at Slough and also work at present being done for D.S.I.R. at the Telecommunications Research Establishment at Malvern. Dr. Smith-Rose has been Superintendent of the Radio Division of the National Physical Laboratory since 1939.

OBITUARY

Mr. W. H. Pick, B.Sc., F.C.P., F.Inst.P. It is with very great regret that we have to record the death of Mr. William H. Pick on Boxing Day, December 26, 1947. His passing will leave a distinct gap in the staff of the Meteorological Office, while he will be missed by an even wider circle of friends in the Royal Air Force.

He was born in Hackney on January 14, 1891, and educated in London. Adopting teaching as a profession, he took his teaching diploma from the London Day Training College, after first graduating in science from University College, London, in 1911. He began his teaching career at Basingstoke and it was while here that he first showed his interest in meteorology. With the help of his pupils he maintained an observing station there for several years which sent in returns to the Meteorological Office.

He joined the Meteorological Section, R.E., in 1917, and was commissioned in 1918. On the cessation of hostilities on the Western Front he was placed in charge of the Meteorological Detachment serving with the British Forces in north Russia.

In early 1920 after his release from the forces he joined the staff of the Meteorological Office as a Senior Professional Assistant and was posted to the Royal Air Force College at Cranwell where he lectured on meteorology for many years. There was at that time no suitable text-book for his students and the preparation of one, "A Short Course in elementary meteorology", occupied his attention for some time. It was a task for which his early training and natural bent eminently suited him and the publication was an immediate success; edition after edition was called for. He was promoted to Assistant Superintendent in 1922.

The Meteorological Office, Cranwell, during his service, was the training station for several newcomers to the professional staff who will remember with especial gratitude his inspiring and wise teaching.

In 1928 he left Cranwell to become a senior forecaster at Headquarters.

In 1932 he was posted to Andover, at that time the headquarters of Wessex Bombing Area. Blind flying in cloud and its attendant risks of icing and collision was then one of the major problems of the Royal Air Force, and he later compiled a comprehensive report on the meteorological aspects of cloud and blind flying. Following the introduction of the " Carpenter " scheme in 1935 he was assimilated as Senior Technical Officer.

The outbreak of the second world war found him meteorological advisor to Bomber Command. This was followed by periods of service at Headquarters in London, with the Ministry of Home Security and Anti-Aircraft Command. The end of the war, however, found him again occupied with the training of pilots at South Cerney. He was assimilated to the grade of Principal Scientific Officer on the introduction of the Scientific Civil Service in 1946. It was while still at South Cerney that the end came so unexpectedly.

Pick's largest contribution to the literature of meteorology was the " Short Course in Elementary Meteorology " which, written originally for the cadets at Cranwell, became very popular in schools throughout the country. Pick was a keen investigator of meteorological problems and was particularly interested in visibility. His papers on that subject published as *Professional Notes* or in the *Quarterly Journal of the Royal Meteorological Society* dealt with downward visibility from the air, visibility in saturated air, the connexion between air-mass type and visibility, and the visibility experienced at Cranwell in different wind directions and speeds. In addition, he wrote a *Professional Note* on the upper wind observations made under his direction in north Russia, articles in the *Quarterly Journal* on the persistence of types of pressure distribution over the British Isles and on mammato-cumulus cloud, and in this magazine on the forecasting of night-minimum temperatures.

Pick was very interested in educational psychology and wrote various papers on that subject in educational journals. He wrote also many articles and character sketches for *Blighty*, some of the London magazines and the *Royal Air Force Quarterly*. These were characterised by a real delicacy of touch which savoured not a little of that master of pastoral lyrics, Robert Herrick, from whose relatives he traced descent.

An interesting example of his combination of educational and meteorological ability was his thesis on the " Teaching of meteorology in Secondary Schools " for which, with his " Short Course", he was awarded in 1922 the Diploma of Fellowship of the College of Preceptors. His abilities as a teacher made him at one time in considerable demand as a lecturer to schools and societies mainly on meteorological topics.

He was for many years a Fellow of the Royal Meteorological Society, serving on its Council and occupying himself particularly with financial matters from 1931 to 1936. He was also a Fellow of the Chemical and Royal Astronomical Societies and of the Institution of Physics.

Pick was held in very high regard in the Royal Air Force, especially by his former pupils at Cranwell, many of whom had risen to senior rank. He was of independent character maintaining his point of view with persistence, even vehemence. A man of wide reading on many topics, he was an entertaining companion in leisure hours.

He married late in life in March 1944 and we would like to extend to his widow our deepest sympathy in her sorrow.

S. F. WITCOMBE

REVIEW

The correlation between weather and yield of winter wheat in the Netherlands, by J. P. M. Woudenberg, Koninklijk Nederlandsch Meteorologisch Instituut, No. 102, Mededeelingen en Verhandelingen 50. 8vo., $9\frac{1}{2}$-in. × $6\frac{3}{4}$-in. pp. 43. (English summary pp. 39-42). 's.Gravenhage, 1946.

This paper is divided into two sections, the first of which contains a large number of useful correlation coefficients, laborious to compute but making good use of crop and weather data, for the three regions, Gröningen, Zeeland and south Limburg. In the second section these data are used to describe the ideal climate for winter wheat, but the results are unconvincing. Any appreciation of this paper must therefore deal with the two sections separately.

In the first section the general trends of the yields are first eliminated and then, for each region, some 80 or 90 correlation coefficients are calculated between the adjusted yields and the rainfall, sunshine and temperature over various periods of the year. The largest of these coefficients between the yield and each element are then combined into multiple correlation coefficients (called " total correlation coefficients " in this paper). For each region these coefficients are about 0·7, and they relate the yield to June and July rainfall and sunshine and to winter temperatures. It would have been useful if the author had given some indication of the statistical significance of his coefficients, but this omission is not serious as sufficient information is given for estimating the significance levels.

In the second section of the paper, the coefficients, together with some other material, are used to define the ideal climate for winter wheat in each locality. However, the definitions include phrases such as " not too mild " and " rather dry ", and they are of very little use. They purport to describe the ideal weather during seven periods between sowing and harvest and for each year (about 1921–40) the weather is assessed by awarding marks for the various periods; the yield of winter wheat is then estimated from the annual totals. Except for south Limburg, the computed yields are close to the actual yields, but the author admits that his method is " very subjective " and it is very doubtful whether different estimates would be comparable. However, there is a more serious objection to the methods of this second half of the paper—the treating of a fundamentally biological problem by purely statistical methods. This fault also the author admits by implication when he points out that the ideal climate applies only to normal years and that it must be changed after very cold winters or very mild springs. There can be little doubt that whenever the weather is very different from the average the ideal climate for the plant from that time onwards in that season will change, and that to speak of a mean " ideal climate " ignores both the variability of the weather in these latitudes and the adaptability of the plant.

W. H. HOGG

WEATHER OF DECEMBER 1947

Pressure was high over the Arctic at the beginning of the month with depressions over Europe and the North Atlantic from the 1st to 8th. These were especially severe between Newfoundland and Greenland, where pressure fell below 972 mb. on the 6th and 968 mb. on the 8th. On the 9th a developing anticyclone spread over the British Isles and became intense, persisting until the 19th; on the 17th pressure exceeded 1044 mb. north of Ireland. On the 20th to 24th it receded south-west and then south and weakened, while pressure was generally low over the Arctic, especially to the north of Europe. On the 24th and 25th a deep depression developed over Iceland, and conditions were very stormy in north-west Europe until the 28th; on the 27th pressure at Wick (Scotland) fell to 966 mb. North-westerly winds in the rear of this depression brought cold conditions and snow during the last three days of the month.

The map of mean pressure distribution shows an area of pressure exceeding 1020 mb. over north-east Greenland, from Madeira to Portugal and south of the Great Lakes of America. Pressure was below 1005 mb. between Newfoundland and South Greenland and in the north of Norway, and was generally low over Scandinavia. The greatest deficits of pressure from normal (exceeding — 5 mb.) lay between Nova Scotia and Newfoundland, and over central Europe and the Baltic; pressure was considerably above normal in the Arctic, central and eastern North Atlantic, Ireland and Scotland, the excess exceeding 10 mb. between Iceland and north-east Greenland.

The weather of the British Isles was generally dry, rather mild and dull. There were cold spells at the beginning and end of the month, particularly during the first three days but roughly from the 5th to 25th it was mainly mild and over much of England and Wales the mild weather persisted until the 28th. In the opening days a wedge of high pressure moved north over Great Britain and some unusually low temperatures were registered; for example, 6°F. at Kelso and Dalwhinnie on the 2nd and Braemar on the 3rd, and 11°F. at Porton on the 1st and Ampleforth on the 2nd. A minimum temperature of 20°F. at Edinburgh on the 2nd was the lowest recorded there in December since 1908. Day temperatures were also very low. On the 5th a deep depression over the Bristol Channel moving north caused moderately heavy rainfall in the south of England and rather severe gales in the south-west; gusts of 77 and 73 m.p.h. were registered at Pendennis Castle and St. Ann's Head respectively. Some snow and sleet showers occurred during the first five days.

A change to very unsettled conditions took place on the 24th; local gales were reported daily from the 25th to 29th, while heavy rainfall occurred at times, particularly in Wales on the 26th. Widespread wintry precipitation occurred on the 29th and 30th, falls of snow up to six inches being reported on Donside, Aberdeenshire. On the closing day a ridge of high pressure moved east over the country, but it was quickly followed by troughs associated with an Atlantic depression and rain spread to all districts by the evening.

The table below shows that there was a considerable deficiency of rainfall, particularly in Scotland. Rainfall exceeded the average, however, in the extreme north of the Scottish mainland, over part of the West Riding of Yorkshire, in an area covering east England from south Norfolk to east Kent and including the Thames estuary, at a few scattered places elsewhere in England, and locally in counties Armagh and Down.

The duration of bright sunshine was appreciably below the average but the percentages at individual stations were irregular, the variation being partly due to the incidence of fog. In Scotland and Northern Ireland a deficiency was practically general, but locally in the eastern half of England and the northern Midlands more than the average was registered.

The general character of the weather is shown by the following table:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	58	11	+1·2	83	−3	87	15
Scotland	58	6	+0·6	58	−4	74	11
Northern Ireland ..	55	18	+1·1	76	−7	57	13

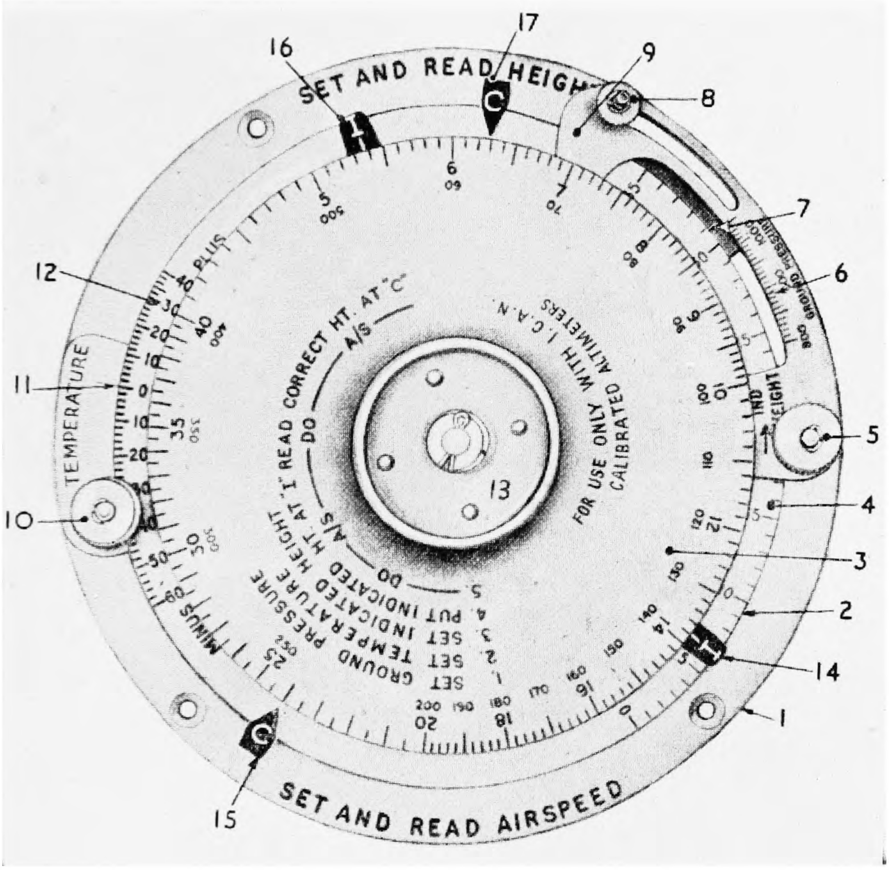
RAINFALL OF DECEMBER 1947

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	2·27	95	*Glam.*	Cardiff, Penylan ..	3·68	73
Kent	Folkestone, Cherry Gdns.	3·41	106	*Pemb.*	St. Ann's Head ..	4·20	88
,,	Edenbridge, Falconhurst	2·69	82	*Card.*	Aberystwyth	3·65	92
Sussex	Compton, Compton Ho.	3·43	82	*Radnor*	Bir. W. W., Tyrmynydd	6·16	75
,,	Worthing, Beach Ho. Pk.	2·30	76	*Mont.*	Lake Vyrnwy	6·28	90
Hants.	Ventnor, Roy. Nat. Hos.	3·43	104	*Mer.*	Blaenau Festiniog ..	9·51	75
,,	Fordingbridge, Oaklands	3·51	89	*Carn.*	Llandudno	1·63	56
,,	Sherborne St. John ..	3·07	93	*Angl.*	Llanerchymedd ..	2·91	66
Herts.	Royston, Therfield Rec.	2·84	122	*I. Man.*	Douglas, Boro' Cem. ..	2·35	48
Bucks.	Slough, Upton ..	2·53	100	*Wigtown*	Port William, Monreith	2·01	44
Oxford	Oxford, Radcliffe ..	1·76	72	*Dumf.*	Dumfries, Crichton R.I.	2·31	54
N'hant.	Wellingboro', Swanspool	2·26	96	,,	Eskdalemuir Obsy. ..	3·13	45
Essex	Shoeburyness	2·04	111	*Roxb.*	Kelso, Floors	1·84	79
Suffolk	Campsea Ashe, High Ho.	3·37	147	*Peebles.*	Stobo Castle	2·69	71
,,	Lowestoft Sec. School ..	2·18	94	*Berwick*	Marchmont House ..	1·66	59
,,	Bury St. Ed., Westley H.	2·88	120	*E. Loth.*	North Berwick Res. ..	1·61	75
Norfolk	Sandringham Ho. Gdns.	2·40	94	*Midl'n.*	Edinburgh, Blackf'd. H.	2·19	94
Wilts.	Bishops Cannings ..	2·47	75	*Lanark*	Hamilton W. W., T'nhill	2·60	60
Dorset	Creech Grange.. ..	3·71	84	*Ayr*	Colmonell, Knockdolian	2·42	43
,,	Beaminster, East St. ..	3·28	69	,,	Glen Afton, Ayr San. ..	3·42	53
Devon	Teignmouth, Den Gdns.	2·04	48	*Bute*	Rothesay, Ardencraig ..	2·82	52
,,	Cullompton	3·99	91	*Argyll*	Loch Sunart, G'dale ..	3·87	44
,,	Barnstaple, N. Dev. Ath.	3·26	74	,,	Poltalloch	3·10	49
,,	Okehampton, Uplands	6·14	87	,,	Inveraray Castle ..	4·65	47
Cornwall	Bude School House ..	3·80	87	,,	Islay, Eallabus ..	3·03	51
,,	Penzance, Morrab Gdns.	3·46	61	,,	Tiree	3·46	66
,,	St. Austell, Trevarna ..	4·40	72	*Kinross*	Loch Leven Sluice ..	2·08	53
,,	Scilly, Tresco Abbey ..	3·20	68	*Fife*	Leuchars Airfield ..	1·19	49
Glos.	Cirencester	2·03	61	*Perth*	Loch Dhu	3·68	37
Salop	Church Stretton ..	3·02	86	,,	Crieff, Strathearn Hyd.	1·89	42
,,	Cheswardine Hall ..	2·74	97	,,	Blair Castle Gardens ..	1·83	48
Staffs.	Leek, Wall Grange P.S.	2·95	79	*Angus*	Montrose, Sunnyside ..	1·90	68
Worcs.	Malvern, Free Library	2·26	82	*Aberd.*	Balmoral Castle Gdns...	2·08	62
Warwick	Birmingham, Edgbaston	2·28	85	,,	Aberdeen Observatory	2·37	74
Leics.	Thornton Reservoir ..	2·31	86	,,	Fyvie Castle	2·35	69
Lincs.	Boston, Skirbeck ..	2·02	94	*Moray*	Gordon Castle	1·61	60
,,	Skegness, Marine Gdns.	2·17	99	*Nairn*	Nairn, Achareidh ..	1·43	70
Notts.	Mansfield, Carr Bank	2·25	78	*Inv's*	Loch Ness, Foyers ..	2·00	45
Ches.	Bidston Observatory ..	1·98	75	,,	Glenquoich	7·06	48
Lancs.	Manchester, Whit. Park	2·75	85	,,	Fort William, Teviot ..	3·59	35
,,	Stonyhurst College ..	4·45	92	,,	Skye, Duntuilm ..	3·42	55
,,	Blackpool	2·78	85	*R. & C.*	Ullapool	3·99	66
Yorks.	Wakefield, Clarence Pk.	2·54	105	,,	Applecross Gardens ..	3·59	56
,,	Hull, Pearson Park ..	2·12	88	,,	Achnashellach	4·24	45
,,	Felixkirk, Mt. St. John	2·17	90	,,	Stornoway Airfield ..	4·02	68
,,	York Museum	1·79	80	*Suth.*	Lairg	2·26	56
,,	Scarborough	1·34	56	,,	Loch More, Achfary ..	9·32	101
,,	Middlesbrough.. ..	1·41	73	*Caith.*	Wick Airfield	3·53	115
,,	Baldersdale, Hury Res.	3·72	100	*Shet.*	Lerwick Observatory ..	3·70	77
Norl'd	Newcastle, Leazes Pk.	2·44	104	*Ferm.*	Crom Castle	3·33	80
,,	Bellingham, High Green	1·89	52	*Armagh*	Armagh Observatory ..	3·18	102
,,	Lilburn, Tower Gdns...	2·23	85	*Down*	Seaforde	4·29	104
Cumb.	Geltsdale	2·39	63	*Antrim*	Aldergrove Airfield ..	1·67	49
,,	Keswick, High Hill ..	2·73	41	,,	Ballymena, Harryville..	2·75	62
,,	Ravenglass, The Grove	1·96	43	*Lon.*	Garvagh, Moneydig ..	2·44	61
Mon.	Abergavenny, Larchfield	2·72	61	,,	Londonderry, Creggan	3·41	78
Glam.	Ystalyfera, Wern House	6·23	75	*Tyrone*	Omagh, Edenfel ..	3·00	71

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, AUGUST 1947

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and ½ Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hrs.	%
London, Kew Observatory	1019·9	+5·0	87	49	77·5	58·8	68·1	+5·9	60·7	69	5·1	0·40	−1·84	4	8·4	58
Gibraltar	1014·6	−1·9	98	65	85·5	70·3	77·9	+1·9	72·1	81	2·5	0·00	—	0	—	—
Malta	1013·4	−1·4	95	69	89·4	74·8	82·1	+3·0	75·4	60	1·8	0·28	—	2	11·2	83
St. Helena	1018·5	−1·4	69	52	61·1	54·0	57·5	+0·2	54·0	96	9·8	2·08	−0·58	21	—	—
Freetown, Sierra Leone	1013·1	+2·0	85	69	80·3	73·9	77·1	+0·8	75·1	92	8·8	43·85	+7·28	31	2·1	17
Lagos, Nigeria ..	1013·7	+0·7	85	68	82·1	71·5	76·8	−1·1	74·7	90	9·5	8·80	—	21	1·4	11
Kaduna, Nigeria ..	1012·2	—	88	64	81·9	67·5	74·7	+0·5	70·6	87	9·3	15·24	+2·92	27	3·7	30
Chileka, Nyasaland ..																
Salisbury, Rhodesia ..																
Cape Town ..	1019·7	−0·6	74	41	63·9	47·9	55·9	+0·3	50·6	88	5·8	2·51	−0·86	17	—	—
Germiston, South Africa	1022·4	—	79	29	72·4	44·6	58·5	—	45·5	40	0·3	0·00	—	0	10·5	94
Mauritius	1022.1	+1.5	79	55	75.2	62.1	68.7	+0.2	62.4	73	4.9	2.15	−0.10	23	8.0	70
Calcutta, Alipore Obsy.	1001·7	+1·0	95	75	89·5	79·5	84·5	+1·3	80·3	91	8·5	15·34	+1·96	26	4·2	33
Bombay	1004·4	−1·5	90	74	86·3	77·4	81·9	+1·1	77·6	88	8·9	20·56	+6·11	21	2·8	22
Madras	1004·4	−1·1	99	74	92·0	78·6	85·3	−0·7	76·8	76	7·1	2·92	−1·62	11	6·0	48
Colombo, Ceylon ..	1008·7	−0·6	87	73	84·4	76·7	80·5	−0·7	75·7	84	8·9	9·23	+5·99	19	4·3	35
Singapore	1008·6	−0·9	91	71	87·7	74·5	81·1	0·0	77·4	80	—	6·85	−1·10	18	—	—
Hongkong	1007·6	+2·8	95	74	87·5	77·6	82·5	+0·4	78·5	86	—	22·62	+8·22	24	6·1	47
Sydney, N.S.W. ..	1017·1	−1·1	81	39	63·9	47·1	55·5	+0·5	47·6	63	4·3	1·68	−1·29	10	6·9	65
Melbourne	1016·3	−1·7	66	32	57·0	42·5	49·7	−1·3	44·3	70	6·9	1·27	−0·60	15	3·7	35
Adelaide	1019·0	−0·2	71	39	59·9	46·0	52·9	−1·1	47·7	68	6·7	3·05	+0·51	15	5·0	46
Perth, W. Australia ..	1019·6	+0·7	73	37	63·9	46·3	55·1	−0·9	51·1	66	5·0	2·15	−3·50	12	6·4	59
Coolgardie	1020·7	+1·4	79	31	65·0	43·1	54·1	+0·5	46·2	63	4·3	0·19	−0·80	5	—	—
Brisbane	1018·9	−0·3	78	44	70·6	51·5	61·1	+0·7	53·9	60	4·5	0·50	−1·51	6	6·7	60
Hobart, Tasmania ..	1010·0	−3·4	64	33	54·6	40·2	47·4	−0·6	41·8	68	7·1	3·24	+1·41	19	6·2	60
Wellington, N.Z. ..	1013·6	−1·5	65	33	54·2	42·7	48·5	+1·2	45·7	80	7·6	4·89	+0·40	18	4·7	45
Suva, Fiji	1014·6	+0·4	84	64	78·5	68·8	73·7	+0·1	70·0	82	7·2	3·05	−5·24	19	4·2	37
Apia, Samoa ..	1012·0	−0·3	89	67	85·8	72·8	79·3	+1·5	74·8	75	6·0	3·03	−0·60	11	7·1	61
Kingston, Jamaica ..	1014·6	+1·1	94	72	90·5	75·1	82·8	+1·3	75·0	71	4·0	3·18	−0·37	7	8·3	65
Grenada, W. Indies ..	1014·7	+2·1	88	72	85·9	76·0	80·9	+1·2	77·2	79	7·1	6·92	−2·41	22	—	—
Toronto	1018·4	+3·0	93	49	82·2	64·5	73·3	+6·1	64·9	84	4·4	2·36	−0·43	5	8·2	59
Winnipeg	1011·6	−1·6	96	39	78·3	57·9	68·1	+4·3	58·6	93	5·5	4·53	+2·37	15	8·7	60
St. John, N.B. ..	1018·3	+3·0	78	47	72·2	56·2	64·2	+3·6	58·7	85	6·1	1·01	−2·85	9	8·5	60
Victoria, B.C. ..	1015·6	−1·3	78	42	71·2	48·3	59·7	0·0	50·3	90	4·0	0·27	−0·37	5	10·2	71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11 Index mark
12 Temperature scale
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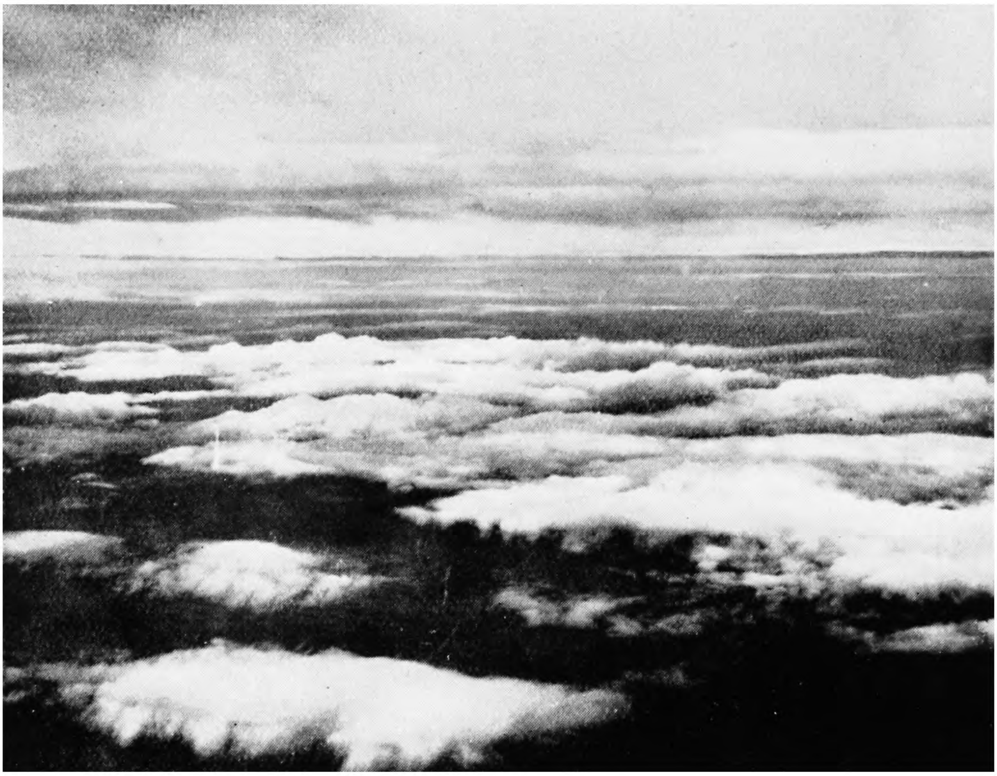
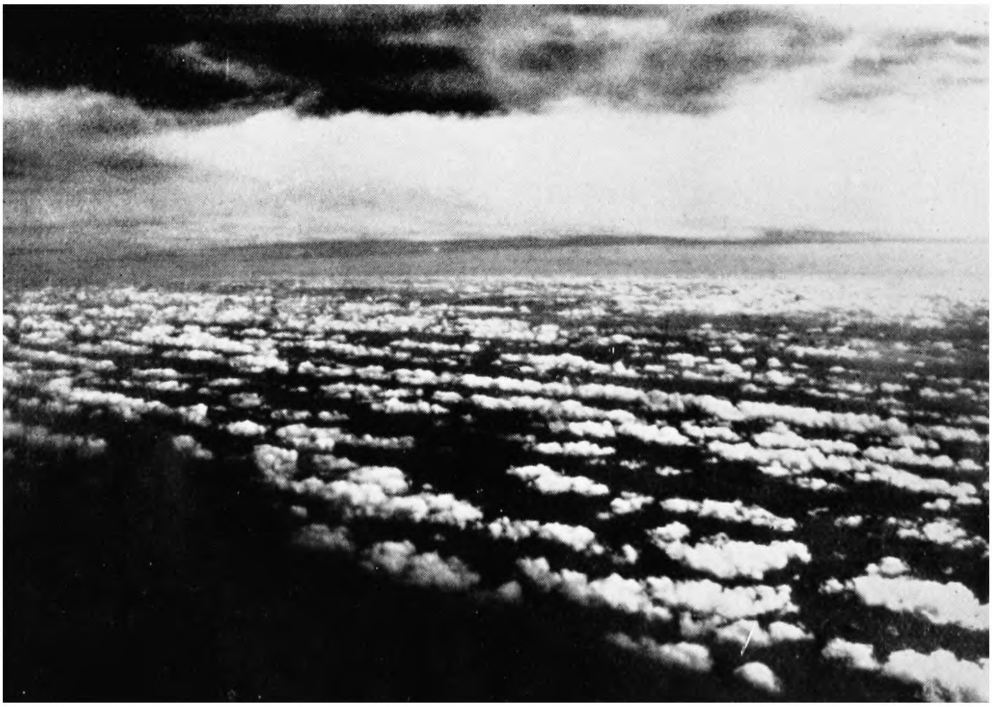
(see p. 29)



Photograph by R.A.F.

ALTOCUMULUS CASTELLATUS OVER WITHERNSEA

Taken from 22,000 ft., September 23, 1943



Photograph by R.A.F.

CUMULUS AND FRACTOCUMULUS OVER THE SEA AT 54°00′N. 6°20′E.

Taken from 26,000 ft. looking east by south, September 6, 1944

M.O. 501 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

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THUNDERSTORM OBSERVATIONS

BY R. H. GOLDE

British Electrical and Allied Industries Research Association

Object of investigation.—Thunderstorms constitute the most impressive form of electrical discharge in nature and their various manifestations have been described from ancient times. In addition to their intrinsic interest the observation of thunderstorms and, in particular, of the lightning discharges associated with them has, in modern times, assumed a direct importance in connexion with the service provided by electrical overhead transmission systems on which lightning incidents have proved the most frequent single source of trouble. In fact, interruption of supply and damage to electrical equipment is experienced so frequently during thunderstorms that great benefit would result if methods were found to improve the safety of operation of supply systems under lightning conditions.

With this aim in mind a nation-wide investigation of lightning faults on electrical supply systems is being undertaken by the Electrical Research Association. This investigation is planned on a statistical basis, and it is clear that a correlation between lightning faults on overhead lines and the occurrence of thunderstorms constitutes one of the most important aspects of this work. The latter factor is of a meteorological nature and depends for its successs on the availability of extensive and reliable data on the occurrence of thunderstorms over the British Isles. The present notes are written with a view to acquainting meteorologists, both professional and amateur, with the object of the investigation, and to enlist the co-operation of those who may be in a position to supply future information in connexion with the above work, which is directly concerned with a matter of national importance.

Frequency of lightning flashes.—Published statistical data on the frequency of thunderstorms[1, 2*] are based on the number of days on which thunder is heard, which, for any district, is called its " isokeraunic level ". This definition has been accepted internationally, but its relevance for practical problems has been repeatedly criticised. First, the isokeraunic level gives no indication of the severity of individual storms,[3] and secondly, it does not differentiate between storms producing lightning flashes which are principally confined to the clouds and those which reach earth.[4] From the view point of the protection against lightning—either of living beings, or structures, or electrical transmission systems—lightning flashes between clouds are of no direct interest.

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*The index figures refer to the list of references on p. 53.

Having regard to this importance of the frequency of occurrence of flashes to earth, critical surveys have been undertaken of relevant information.[5] From one such investigation[5] a tentative indication has been derived that, in temperate regions, the number of lightning flashes to one square mile of ground is about equal to one half of the respective isokeraunic level.

It must be emphasised that even if the foregoing relation is correct, it merely constitutes an average value taken over long periods and covering considerable areas. Now it is well known that the storm activity may vary greatly between different localities and from year to year. In fact, the severity of exceptionally heavy storms may be such as to produce, in a single day, the bulk of the total annual failures on an electrical overhead system. Thus on one system covering an area of about 1,200 sq. miles practically all faults due to lightning experienced in one year—and these amounted to over 100—occurred in the course of 2 days.

Principal types of lightning discharges.—While it is beyond the scope of these notes to discuss in detail the various types of lightning discharges[7] which have been observed, a brief enumeration of the principal characteristics of the most common types of discharge may be of value. These can be subdivided most conveniently into discharges between cloud and earth, and discharges between different parts of a cloud.

Flashes to earth normally start inside a charge centre of a thundercloud and are propagated towards earth in the form of a so-called " leader stroke ". On reaching earth the leader stroke, which can only be detected by means of fast-moving cameras, is followed by the main " return stroke " which follows in every detail the trail blazed by the leader stroke and which, on account of the high current discharged through it, constitutes the path visible to the unaided observer. About one half, roughly, of such flashes to earth are confined to a single discharge channel (Fig. 1), while the other half shows more or less pronounced branching, forked lightning (Fig. 2). As the direction of branching of electrical discharges is independent of polarity and always occurs in the direction of the initial propagation of the discharge, branches of normal lightning strokes to earth are always inclined downwards.

In contradistinction to the foregoing normal flash to earth, flashes to very tall earthed objects, such as wireless masts, balloon cables and so on, may be initiated at the top of the structure from where the usual leader stroke would then be propagated towards the cloud, while the return stroke would flow from the cloud towards the structure. Branching in this case would be directed upwards.

Multiple-stroke flashes to earth (Figs. 3 and 4), which may occur in both the foregoing cases, are characterised by the repetition of the leader and return stroke process described above, along the original discharge path. Occasionally one of the later strokes in such a flash may follow an alternative branch near earth, thus giving a still picture of a bright forked flash to earth. Such multiple-stroke flashes may discharge up to twenty or more individual strokes covering a total duration of about a second, and they can be recognised by a pronounced flicker of the discharge. They are believed to be caused by the tapping of surrounding cloud-charge centres, the distances between which may be several miles, i.e. several times the distance covered by the initial discharge to earth. A multiple-stroke flash can therefore consist of a discharge to earth together with long and more or less horizontal discharges in or just below the cloud.

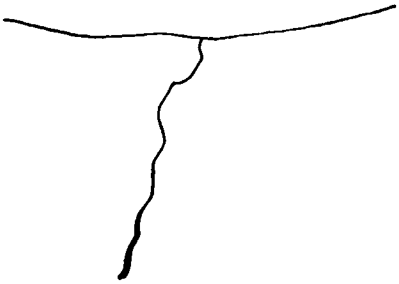

FIG. 1—SINGLE UNBRANCHED FLASH

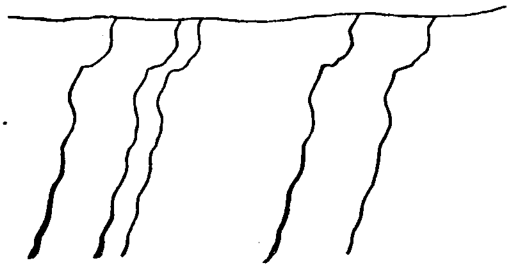

FIG. 3—MULTIPLE-STROKE FLASH UNBRANCHED RECORDED WITH MOVING CAMERA

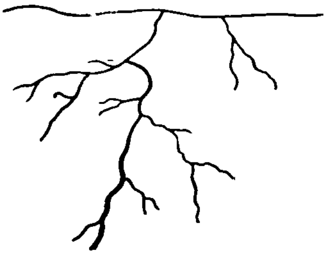

FIG. 2—SINGLE BRANCHED FLASH

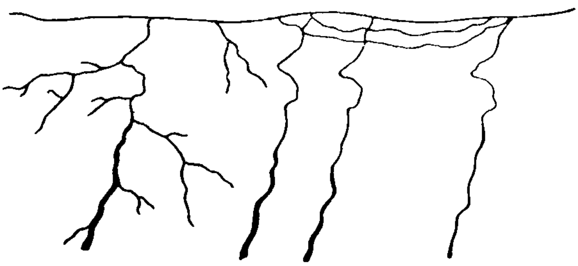

FIG. 4—MULTIPLE-STROKE FLASH BRANCHED RECORDED WITH MOVING CAMERA

Cloud-to-cloud flashes are less susceptible to visual or photographic investigation than flashes to earth and less is known about them. The term, cloud-to-cloud flashes embraces a variety of discharges between different charge centres in a thundercloud or even from the cloud into the upper atmosphere. However, for the present purpose no further subdivision is necessary as the immediate interest is concentrated on flashes reaching earth.

Sound of thunder.—In the sound of thunder produced by a normal lightning discharge two types can sometimes be distinguished: a short sharp crack and the familiar long-drawn rumbling.

The sharp crack of thunder which has frequently been described in literature[4] is produced by the compression wave caused by the sudden expansion of the discharge channel during the heavy return stroke. This sound is rapidly attenuated with distance and is absent in cloud-to-cloud discharges. It is particularly noticeable in lightning flashes which strike earth at a short distance from the observer.

While the violent sharp crack will be recognised without difficulty by any observer who has experienced flashes to earth within a few hundred feet, it should not be mistaken for a swishing noise which frequently precedes a thunder clap. This latter is likely to be produced by discharges which may only be visible at night, and which arise from pointed earthed bodies as a result of the sudden field change caused by a lightning discharge. As these field changes are propagated with the speed of light (186,000 mi./sec.), whereas ordinary thunder is propagated with the speed of sound (1,085 ft./sec.), the swishing sound reaches the ear of an observer well in advance of the proper thunder clap. However, since the field changes caused by flashes to earth and by cloud-to-cloud flashes are of a similar order of magnitude, the swishing sound cannot be used to differentiate between these two types of discharge.

The well known rumble of thunder is due to the great distances covered in the cloud by some lightning discharges to which reference has already been made. As the duration of even the longest discharge rarely exceeds 1 sec. this is negligibly small compared with the time taken by the thunder to reach an observer who may be close to one end of a discharge but possibly 5 to 10 miles away from its other end in the cloud.

It thus appears that a sudden crack followed by the ordinary rumbling noise can be taken as an indication of a lightning flash to earth, but its value as a means of recognising such discharges is limited by the comparatively short distances over which it can be recognised.

Methods of recording lightning flashes.—The problem of reporting the occurrence of thunderstorms producing lightning discharges to earth would be greatly simplified if methods for automatic recording were available. Several kinds of instruments designed for specific purposes are in existence which record thunderstorms up to great distances. These are based fundamentally on three major principles: the recording by means of an electrometer-type of instrument[8,9] or by a cathode ray oscillograph [0,11] of electric field changes produced by lightning discharges, the reception on a selected wavelength of the atmospherics [2] produced by lightning discharges, and the recording of the current discharged into the atmosphere from a fine earthed point[13,14] installed at some height above earth.

Each of these instruments has, in its own field of application, greatly extended our knowledge of lightning phenomena, but none of these methods can be applied to the problem under discussion. The last-named methods are so far incapable of distinguishing between cloud-to-cloud flashes and flashes to earth, while the first method involves prohibitive expense in addition to technical complications.

Proposed census of thunderstorms.—From what has been said above it follows that no simple instrument is available by which to differentiate between cloud-to-cloud flashes and flashes to earth. In these circumstances it is necessary to seek the help of voluntary observers who have contributed so much to the statistical information from which most meteorological data have been obtained.

For the convenience of those who may be willing to co-operate in the work outlined, postcards will be provided on which the following information will be requested:—

(1) Approximate time and duration of storm.
(2) Direction of movement of storm.
(3) Severity of storm.
(4) Estimate of number of lightning flashes to earth.

The following comments may be pertinent in connexion with the individual items mentioned.

The approximate time and duration of storm is intended to serve as a means of correlating and checking the times of failures of electricity supply reported by supply undertakings.

The direction of movement of storm will provide an indication of storm movements in areas with a low density of observers.

The severity of the storm cannot be readily defined, but an observer should find no difficulty in making brief qualitative statements, such as: a few rumbling noises of distant thunder, a few lightning flashes with lengthy time intervals, continuous lightning activity during the passage of thunderclouds, several intense flashes of lightning from a local stationary cloud, violent and prolonged lightning activity which was first noticed at a distance, then proceeded overhead, and finally disappeared in the direction mentioned under (2), etc.

An estimate of the number of lightning flashes to earth would be most valuable for the present investigation, but may undoubtedly be open to considerable ambiguity. Such an estimate is necessarily influenced by the field of vision of the observer, by the time of day or night of the occurrence of the storm, by the height of the thundercloud, and by visibility and other atmospheric factors, all of which may reduce the chance of observing flashes to earth. While these difficulties are recognised it should be emphasised that the information requested is not intended to be used for a statistical evaluation of the density of lightning flashes to earth, but as an indication of the potential danger of the particular storm to any electrical overhead line in the area concerned. Thus it will be sufficient to give, under this heading, general statements like: no flashes to earth noticed, a small percentage of the flashes went to earth, few but distinct flashes to earth, many flashes to earth, etc. If in addition an approximate indication can be given of the number of flashes to earth, *e.g.* so many strokes to earth per minute, during the height of the lightning storm, this information in conjunction with the total duration of the storm will be most valuable for the purpose of this investigation.

Conclusions.—Valuable information on the behaviour of different types of electrical transmission lines under lightning conditions can be obtained if the number of faults due to lightning on any particular line can be correlated with the lightning activity of the area concerned. Statistical information on lightning faults on electrical supply systems is being collected. To obtain the complementary information on the occurrence and severity of lightning storms an appeal is made for the co-operation of observers in England, south Scotland and Wales. Interested potential observers are requested kindly to write to the British Electrical and Allied Industries Research Association, 5 Wadsworth Road, Perivale, Middlesex.

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LONDON TEMPERATURES

BY W. A. L. MARSHALL

The bourdon tube of the mercury-in-steel distant recording thermograph from which the temperatures on the roof of the Meteorological Office, Victory House, Kingsway, London, are supplied to the Press is exposed in a small Stevenson screen, 122 ft. above street level and 3 ft. above a short parapet to which the screen is bolted. An iron rail 1 ft. 9 in. above this parapet is 6 in. clear of the back of the screen about on a line with the top of the legs. A higher parapet 4-ft. high lies about 40 ft. to the west of the screen. The roof is flat.

The screen is very openly exposed in all directions except to south-south-west, where a projection of the main building 8-ft. high is situated about 45 ft. away; there is no higher roof in the immediate locality. There is no special insulation between the asphalt-covered roof and the wooden legs of the screen. The nearest skylights, opaque and dull, are 20-ft. to the west of the screen.

Thus hourly roof temperatures are available at any time of day or night, a facility that has resulted in their being very widely quoted. The roof exposure, however, differs so substantially from an orthodox exposure that an examination of the extent to which these roof values differ from readings taken at a standard site in inner London is desirable. Maximum and minimum temperature readings at Kensington Palace have been issued as official " London Observations " for many years. Kensington Palace values have therefore been taken as comparable for this purpose, the period reviewed being the twelve months August 1946 to July 1947.

Over the twelve months examined the maximum temperature on the asphalt roof of the Meteorological Office was lower than the maximum temperature on the orthodox site at Kensington Palace from early summer until late autumn. This difference was most pronounced from August to October though there was one occasion in June when the roof was six degrees cooler than near the ground.

From late November to January, however, the trend was different. Maximum temperature was often higher on the roof than near the ground, once by as much as 8°F. This feature was noticeable to a lesser extent in March also. February 1947 was exceptionally cold. In a more normal season the tendency for winter maxima to be higher on the roof than near the ground may hold good from November to March.

The two cases in which day-maximum temperatures on the roof of the Meteorological Office, Kingsway, differed by six degrees or more from the readings at Kensington Palace were December 13, 1946 (V.H. max. = 47°F., K.P. max. = 39°F.) and June 12, 1947 (V.H. max. = 62°F., K.P. max. = 68°F.)

> December 13 was a foggy day in the London area, the fog varying in persistence and intensity. At Kew Observatory, where dense fog persisted all day, the maximum temperature was only 36°F., yet at Croydon there were 4 7 hr. of bright sunshine after early morning fog and the temperature there reached 46°F. On the roof of Victory House temperature rose from 36°F. at 0900 G.M.T. to 47°F. at 1400, while visibility improved from 50 yd. at 0900 to 500 yd. by midday.
>
> June 12 was a sunny day but with moderate easterly winds. Maxima in the London area ranged from 62°F. at Croydon and Hampstead to

67°F. at Camden Square. Temperature on the roof of the Meteorological Office rose to 62°F. at 1300 G.M.T. and remained steady until it commenced to fall soon after 1500.

The reason for the above facts is not obvious. In summer the effects of the asphalt roof seem to be more than offset by the effects of height and the more open exposure on the roof than is possible at ground sites in inner London.

TABLE I—DAY-MAXIMUM TEMPERATURE

0900–2100 G.M.T.

Monthly means

	Victory House (V.H.)	Kensington Palace (K.P.)	V.H.—K.P.
	°F.	°F.	°F.
1946			
August..	67·9	69·3	−1·4
September	64·5	65·9	−1·4
October	56·1	57·6	−1·5
November	52·4	52·7	−0·3
December	43·5	42·6	+0·9
1947			
January	41·4	40·5	+0·9
February	33·0	33·5	−0·5
March	47·2	46·7	+0·5
April ..	58·0	58·3	−0·3
May ..	67·3	68·1	−0·8
June ..	71·2	72·3	−1·1
July ..	74·2	75·2	−1·0
Year	56·5	57·0	−0·5

Daily difference (V.H. — K.P.)

Difference (V.H.— K.P.)	1946					1947							Total	
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July		
°F.	*Number of occasions*													%
+8	—	—	—	—	1	—	—	—	—	—	—	—	1	0·3
+7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+5	—	—	—	—	2	1	—	—	—	—	—	—	3	0·8
+4	—	—	—	2	1	2	—	—	—	—	—	—	5	1·4
+3	—	—	—	—	1	1	—	2	—	—	—	—	4	1·1
+2	—	—	—	2	2	8	1	5	1	—	—	—	19	5·2
+1	—	1	1	3	7	7	3	6	5	3	1	2	39	10·7
0	3	5	3	7	10	3	10	11	12	10	7	11	92	25·2
−1	16	12	12	10	7	7	11	7	8	10	16	8	124	34·0
−2	10	7	10	4	—	2	2	—	3	6	3	6	53	14·5
−3	1	3	2	2	—	—	1	—	1	1	1	4	16	4·4
−4	1	2	3	—	—	—	—	—	—	1	1	—	8	2·2
−5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−6	—	—	—	—	—	—	—	—	—	—	1	—	1	0·3

In the last few months of the year, when the general trend of temperature is downward, a massive object such as Victory House, by reason of its thermal capacity may have introduced a certain amount of seasonal lag. This may account in part for the relatively higher maxima on the roof in November and December. Victory House was centrally heated during the day-time from the beginning of October until the end of April. This had no appreciable effect on the maximum temperature on the roof in October, and there is thus no reason to suppose that it had any large effect on the maxima on the roof during the remainder of the winter period.

The severe winter of 1946-7 affords an opportunity of comparing the number of occasions on which frost persisted all day on the roof and near the ground.

TABLE II—FROST PERSISTING THROUGHOUT THE DAY

Maximum temperature 32° F. or below

Day maximum	December		January		February		March		Winter 1946–7	
	V.H.	K.P.	V.H.	K.P.	V.H.	K.P.	V.H.	K.P.	V.H.	K.P.
°F.	*Number of occasions*									
32	—	—	1	—	3	4	1	—	5	4
31	—	1	1	3	4	3	—	—	5	7
30	1	—	1	2	3	6	—	—	5	8
29	—	—	2	—	4	—	—	—	6	—
28	—	—	1	—	—	1	—	—	1	1
27	—	—	—	1	2	—	—	—	2	1
26	—	—	1	—	—	—	—	—	1	—
Total	1	1	7	6	16	14	1	—	25	21

TABLE III—SPELLS OF TWO OR MORE CONSECUTIVE DAYS OF PERSISTENT FROST

Duration	January		February	
	V.H.	K.P.	V.H.	K.P.
days				
3	—	—	1	2
4	—	—	1	—
5	—	1	—	—
6	1	—	—	—
7	—	—	—	—
8	—	—	—	1
9	—	—	1	—

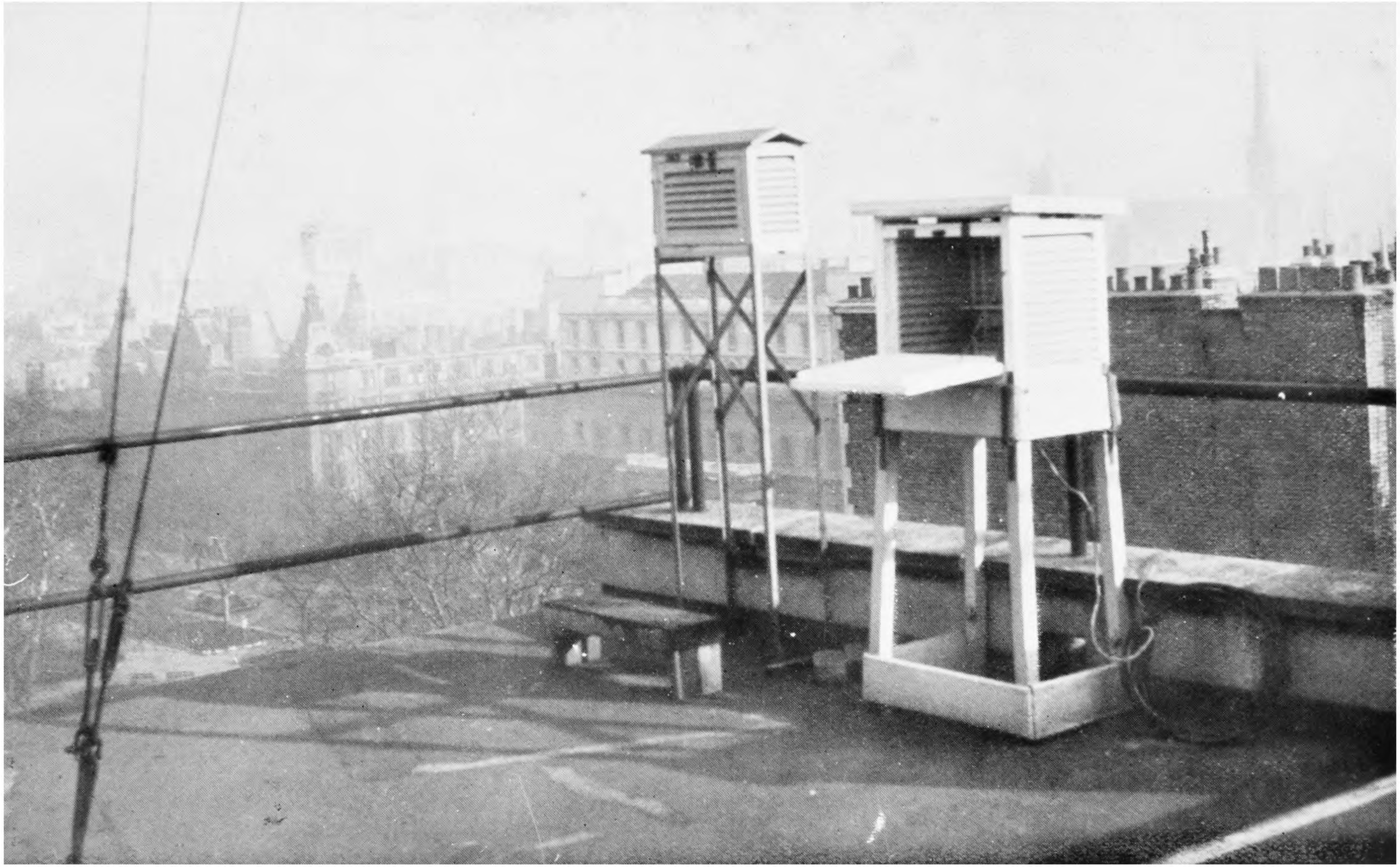
Frosty days were more frequent and more severe on the roof of the Meteorological Office than at 4 ft. above the ground at Kensington Palace.

TABLE IV—NIGHT-MINIMUM TEMPERATURE

2100—0900 G.M.T.

Monthly means

	Victory House (V.H.)	Kensington Palace (K.P.)	V.H.–K.P.
	°F.	°F.	°F.
1946			
August	55·9	54·0	1·9
September	55·0	53·6	1·4
October	48·6	46·9	1·7
November	46·2	44·4	1·8
December	37·3	33·7	3·6
1947			
January	35·5	32·9	2·6
February	29·0	27·8	1·2
March	38·4	35·9	2·5
April	45·4	42·9	2·5
May	52·4	49·9	2·5
June	58·8	55·1	3·7
July	61·2	58·8	2·4
Year	47·1	44·8	2·3



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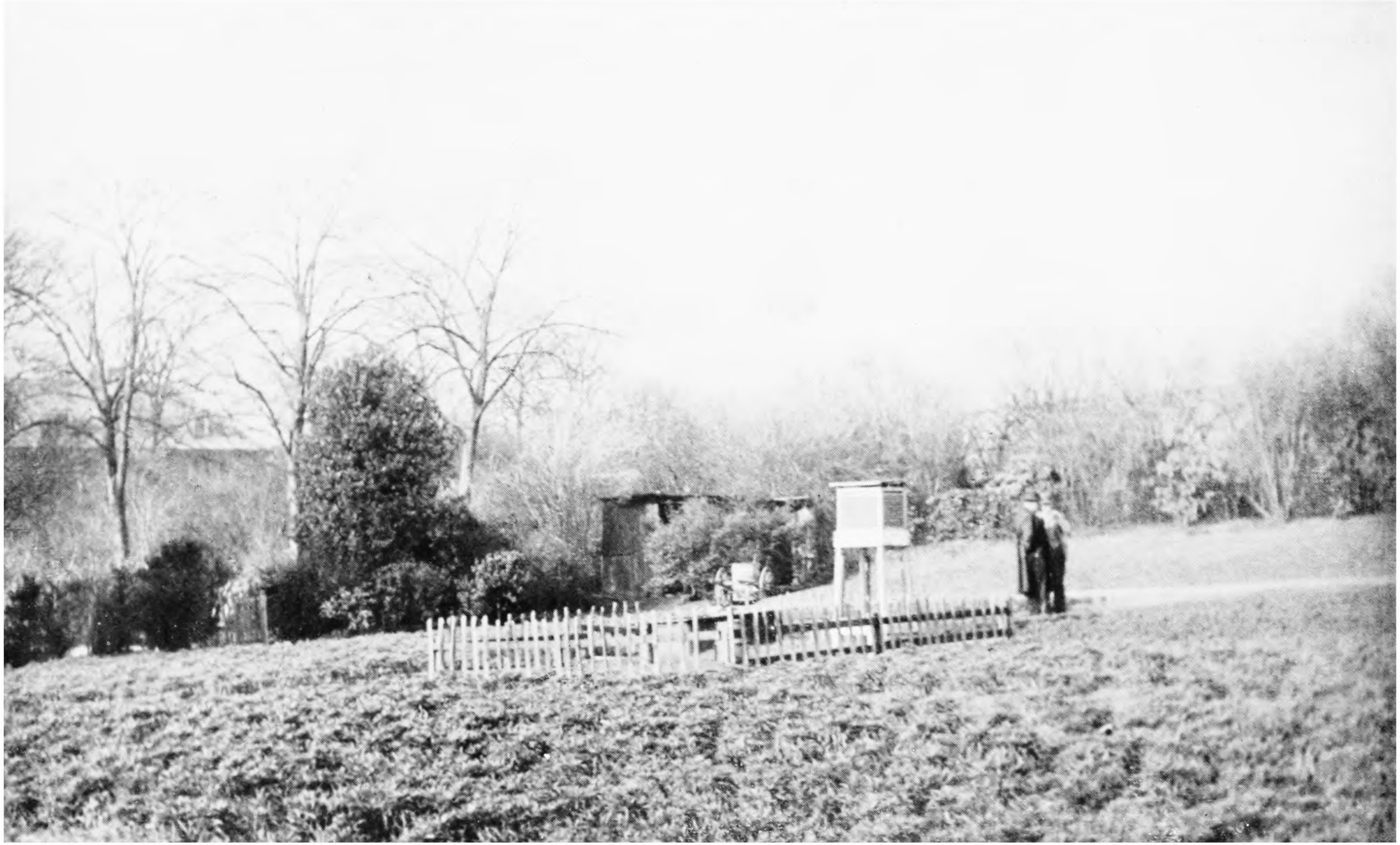
THERMOMETER SCREENS ON ROOF OF VICTORY HOUSE, KINGSWAY
looking south-east

To face p. 57]



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METEOROLOGICAL ENCLOSURE, KENSINGTON PALACE GARDENS
looking north-west

Daily differences (V.H.—K.P.)

Difference (V.H.—K.P.)	1946 Aug.	Sept.	Oct.	Nov.	Dec.	1947 Jan.	Feb.	Mar.	Apr.	May	June	July	Total	
°F.	*Number of occasions*													%
+10	—	—	—	—	—	1	—	1*	—	—	—	—	2*	0·5*
+9	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+8	—	—	1	—	2	1	1	—	—	—	1	—	6	1·6
+7	—	—	—	—	2	—	1	1	1	1	5	—	11	3·0
+6	2	—	1	3	4	1	—	2	3	1	2	—	19	5·2
+5	—	1	1	—	3	4	—	—	1	3	—	1	14	3·8
+4	2	3	3	5	3	3	—	3	3	2	5	5	37	10·1
+3	4	2	3	3	3	1	1	4	5	7	6	8	47	12·9
+2	6	4	4	4	8	9	4	8	6	7	7	10	77	21·1
+1	13	13	10	2	5	7	9	8	8	6	3	5	89	24·4
0	4	7	4	10	1	3	10	3	1	4	1	2	50	13·7
−1	—	—	4	3	—	—	2	1	2	—	—	—	12	3·3
−2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−4	—	—	—	—	—	1*	—	—	—	—	—	—	1*	0·3*

*Doubtful.

The two occasions on which the minimum temperatures on the roof of the Meteorological Office were 10°F. higher than the reported readings at Kensington Palace were January 3, 1947 (V.H. min.=39°F., K.P. min.=29 F.) and March 15, 1947, (V.H. min.=32 F., K.P. min.=22°F.).

The Kensington-Palace value of 29 F. on January 3 is supported by the values at other London observing stations. The value of 22°F. on March 15 is doubtful, all other London ground-level stations reported minima of between 25 F. and 27°F.

The case in which the Meteorological Office night-minimum temperature was four degrees lower than that reported at Kensington Palace was on January 1, 1947, (V.H. min.=37°F., K.P. min.=41 F.). The Kensington 9 a.m. dry-bulb reading was 32°F., a ten-degree error seems to have been made in reading the minimum-temperature thermometer there.

Night-minimum temperatures were consistently higher on the roof than at 4 ft. above the ground. This is in accordance with expectations from considerations of height alone. There was no central heating in Victory House at night during the winter of 1946-7, but the thermal capacity of the building may have tended to reduce the diurnal variation of temperature in its immediate vicinity, and thus have accentuated the December and January differences.

TABLE V—NIGHT FROSTS

Minimum temperature 32 F. or below

Description	Min. temperature	Oct. V.H.	Oct. K.P.	Nov. V.H.	Nov. K.P.	Dec. V.H.	Dec. K.P.	Jan. V.H.	Jan. K.P.	Feb. V.H.	Feb. K.P.	Mar. V.H.	Mar. K.P.	Winter 1946–7 V.H.	Winter 1946–7 K.P.
	°F.	*Number of occasions*													
Slight	32–30	—	1	—	—	3	7	2	5	3	5	3	7	11	25
Keen	29–26	—	—	—	—	4	4	8	7	15	16	4	1	31	28
Hard	25–21	—	—	—	—	—	2	—	2	5	2	1	5	6	11
Severe	20–15	—	—	—	—	—	—	2	1	—	1	—	—	2	2
Very severe	<15	—	—	—	—	—	—	—	1	—	1	—	—	—	2
All frost ranges		—	1	—	—	7	13	12	16	23	25	8	13	50	68

In winter, spring and early summer roof minima were often five degrees higher than at the ground site, once by as much as 10 degrees.

Details of night frosts at the two exposures during the exceptional winter of 1946-7 are given in Tables V and VI.

TABLE VI—SPELLS OF TWO OR MORE CONSECUTIVE NIGHT FROSTS

Duration	December		January		February		March		Winter 1947	
	V.H.	K.P.	V.H.	K.P.	V.H.	K.P.	V.H.	K.P.	V..H	K.P.
Nights					*Number of spells*					
2	—	—	—	—	—	—	—	2	—	2
3	—	1	1	1	—	—	2	—	3	2
5	—	—	—	—	1	1	—	—	1	1
7	1	1	—	—	—	—	—	—	1	1
11	—	—	1†	—	—	—	—	—	1†	—
13	—	—	—	1*	—	—	—	—	—	1*
16	—	—	—	—	1	—	—	—	1	—
27	—	—	—	—	—	1‡	—	—	—	1‡

*January 21—February 2. †January 23—February 2. ‡February 11—March 9.

TABLE VII—DIURNAL TEMPERATURE RANGE

Monthly means

	Victory House (V.H.)	Kensington Palace (K.P.)	V.H.–K.P.	V.H./K.P.
	°F.	°F.	°F.	%
1946				
August	12·0	15·3	−3·3	78
September	9·4	12·3	−2·9	76
October	7·5	10·8	−3·3	69
November	6·2	8·3	−2·1	75
December	6·2	8·9	−2·7	70
1947				
January	5·9	7·6	−1·7	78
February	4·0	5·7	−1·7	70
March	8·8	10·4	−1·6	85
April	12·6	15·5	−2·9	81
May	14·9	18·2	−3·3	82
June	12·4	17·2	−4·8	72
July	13·0	16·4	−3·4	79
Year	9·5	12·2	−2·7	77

Diurnal ranges of specified amounts at Victory House

Range	1946 Aug.	Sept.	Oct.	Nov.	Dec.	1947 Jan.	Feb.	Mar.	Apr.	May	June	July	Year	
°F.						*Number of occasions*								%
28–29	—	—	—	—	—	—	—	—	—	1	—	—	1	0·3
26–27	1	—	—	—	—	—	—	—	—	1	—	—	2	0·5
24–25	1	—	—	—	—	—	—	—	—	—	1	—	2	0·5
22–23	2	—	—	—	—	—	—	1	—	2	—	—	5	1·4
20–21	1	—	—	—	—	—	—	1	4	4	2	1	13	3·6
18–19	2	—	—	—	—	—	—	—	3	2	2	4	13	3·6
16–17	6	—	—	—	—	—	—	1	3	4	5	5	24	6·6
14–15	8	1	2	—	2	1	1	3	1	4	3	5	31	8·5
12–13	1	11	1	3	1	1	2	6	7	4	2	4	43	11·8
10–11	8	4	5	2	3	3	—	1	4	3	7	6	46	12·6
8–9	1	7	6	4	1	7	1	5	2	1	1	3	39	10·7
6–7	—	2	8	7	13	2	1	2	3	2	5	3	48	13·2
4–5	—	4	6	9	4	10	5	3	2	2	2	—	47	12·9
2–3	—	1	3	4	4	4	13	7	1	—	—	—	37	10·1
0–1	—	—	—	1	3	3	5	1	—	1	—	—	14	3·8

Diurnal ranges of specified amounts at Kensington Palace

			1946						1947					
Range	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Year	
°F.	Number of occasions													%
30–31	—	—	—	—	—	—	—	—	—	2	1	—	3	0·8
28–29	—	—	—	—	—	—	—	—	—	2	1	—	3	0·8
26–27	1	—	—	—	—	—	—	—	2	3	3	—	9	2·5
24–25	1	—	—	—	—	—	—	1	2	1	2	1	8	2·2
22–23	2	—	—	—	—	—	1	—	3	4	—	3	13	3·6
20–21	1	—	1	—	1	—	1	—	3	2	2	5	16	4·4
18–19	2	3	3	1	1	—	—	4	2	2	2	5	25	6·8
16–17	6	6	3	2	1	1	—	2	—	3	7	5	36	9·9
14–15	8	3	—	2	2	1	—	2	6	5	3	4	36	9·9
12–13	1	4	6	2	—	4	1	3	5	1	1	2	30	8·2
10–11	8	6	3	3	7	2	—	6	2	1	5	3	46	12·6
8–9	1	1	9	4	9	6	2	1	2	1	3	2	41	11·2
6–7	—	5	2	5	3	5	2	4	1	3	—	1	31	8·5
4–5	—	2	2	8	4	10	10	3	1	1	—	—	41	11·2
2–3	—	—	2	2	2	1	10	4	1	—	—	—	22	6·0
0–1	—	—	—	1	1	1	1	1	—	—	—	—	5	1·4

Night frosts were more frequent, persistent and severe near the ground than at roof level.

With day maxima mainly lower and night minima higher on the roof than near the ground a smaller diurnal temperature range at the higher level follows automatically. Table VII shows the magnitude of the diurnal temperature ranges at the two places and their seasonal variation.

METEOROLOGICAL OFFICE DISCUSSIONS

January 19, 1948. Radiative equilibrium in the ionosphere. By R. v. d. R. Woolley (*Proc. roy. Soc., London*, A, **189**, 1947, p. 129). Opener—Dr. G. D. Robinson.

The paper is concerned with the computation of temperatures from about 100 Km. to the limits of the atmosphere, on the assumption that there is radiative equilibrium at all levels. This question inevitably involves discussion of the constitution of the atmosphere at these heights. The author, developing the methods of E. A. Milne sets up the equation of radiative equilibrium and shows the physical quantities required for a calculation of temperature at any level. These comprise the total absorption per unit volume, and the fraction of absorbed radiation converted to kinetic energy, together with boundary values of the radiative flux and a limited knowledge of the distribution of intensity of radiation with angle. All these quantities must be known for all frequencies. The remainder of the paper consists of a discussion of probable values of these quantities at various heights and consequent estimates of temperature.

In the first region considered the main absorbing agent is molecular oxygen in the dissociation continuum, and the principal infra-red radiator is considered to be water vapour. There is some discussion of the amount of water vapour in the atmosphere, and the author admits a possible tenfold ambiguity. Hettner's absorption coefficients are used, and again the author is aware of the very dubious nature of this assumption. Temperatures of the order of

1,000°A are deduced. Diurnal variation is not explicitly mentioned. The levels to which this analysis is believed applicable are between 100 and 200 Km. At higher levels atomic oxygen is the main absorbing agent (in the ionisation continuum) and the author considers that the main infra-red radiators are negative ions of nitrogen, and dust. He believes negative ions to be relatively most effective between 200 and 300 Km., and deduces temperatures of the order of 1,000°A. for these heights, increasing rapidly as the total population of particles is reduced. Very considerable assumptions regarding the absorption coefficients and the relative concentration of atomic molecules and ions of oxygen and nitrogen are involved. Basing his estimate of the available radiative surface on the observations of the intensity of the zodiacal light the author then computes the effect of dust on the temperature in the very highest regions of the atmosphere, and concludes that this temperature is unlikely to be much below 4,000°A.

There was little time to consider a most interesting section of the paper where the interrelation of temperature and constitution of the atmosphere is discussed and the equilibrium of atomic and molecular oxygen investigated. A side issue of interest to the meteorologist is the author's conclusion that dissociation of the water molecule followed by escape of hydrogen from the earth's gravitational field in the prevailing high temperatures leads to a continuous upward flux of water through the stratosphere. The magnitude of this flux will greatly affect the temperature of at least the lower ionospheric layers.

Speakers in the discussion which followed included Mr. E. Gold (who in 1909 was the first to put forward a fully developed theory of radiative equilibrium in the stratosphere), Dr. A. H. R. Goldie, Dr. J. M. Stagg and Mr. O. M. Ashford. Amongst the points raised were the author's neglect of diurnal and seasonal effects and of the possibility of large scale vertical and horizontal movements of air at certain heights, the relation of the author's views on the composition of the atmosphere to those deduced from a study of auroral spectra, and difficulties in the use of ionic recombination rates (measurable by radio methods) to estimate ionospheric temperatures. In respect of the last point reference was made to the recent results of S. L. Seaton* which conflict in some respects with those of Dr. Woolley.

METEOROLOGICAL RESEARCH COMMITTEE

The 53rd meeting of the Meteorological Research Committee was held on January 29, 1948.

Consideration was given to a new method, proposed by Prof. Simon, for obtaining samples of the upper atmosphere. Briefly the proposal envisages attaching to a radio-sonde balloon a small evacuated vessel cooled by liquid hydrogen. At a predetermined height the vessel would be opened to the outside atmosphere by a valve. The air would rush in and condense as a solid and a second valve would then close the vessel. The cooling of the vessel would ensure a sufficiently large sample being obtained. After discussion of the practical aspects of the proposal it was decided to follow up this suggestion.

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*SEATON, S. L.; Temperature and recombination coefficient in the ionsphere. *J. Met., Milton Mass.*, 4, 1947, p. 197.

Two papers by Dr. Robinson dealt with the subject of turbulence very near the ground. The author presented calculations which indicate that, in the lowest layers, the radiative transfer of heat is as important as the turbulent transfer. It follows that any work on this subject which omits consideration of the radiative transfer of heat is liable to be misleading. A proposed investigation of turbulent transfer near the ground, taking account of all relevant factors, was outlined.

Dr. Stagg presented a comprehensive account of the work done at Kew on solar radiation during the past 16 years.

Other matters discussed included the magnitude of casual variations of temperature in the free air on the basis of measurements made by Dr. Frith.

ROYAL METEOROLOGICAL SOCIETY

In presenting the Report of the Council of the Society for 1947 at the Annual General Meeting on January 21, 1948, the President, Prof. G. M. B. Dobson, referred with satisfaction, to the fact that in spite of the increase in subscription the number of fellows had increased by 75 and to the increase in the sales of *Weather*. Outstanding events were the appointment of an Executive Secretary, the exceptional success of the summer meeting, as the Navy's guests, at Portsmouth, and the formation of the Midland Branch.

There was considerable discussion over the present method of election of the new Council which was considered by some Fellows to give inadequate opportunity for the general body of Fellows to put forward new members of Council.

Messrs. Darton, meteorological instrument makers, generously offered, in 1947, two annual prizes, for the next 3 years, of instruments for presentation by the Society and the first awards were announced by the President. The first prize was awarded to Major Gunton for his work in the preparation of the *Phenological Reports* of the Society and the second to Mr. J. Paton for his work on temperature and humidity conditions in a wheat field. The President announced the Council's decision not to award the Buchan Prize in 1948, because the war had prevented much work which would need to be considered from being published as yet, but to award two prizes in the following year.

The main event of the meeting, the Presidential Address, was then delivered on " Some meteorological aspects of atmospheric pollution." In his opening remarks the President said that now the serious nature of this problem was fully recognised the Society could view with pride the fact that two of its Fellows, Sir Napier Shaw and Dr. Owens, were among the very first to protest against the increasing pollution of city air.

He went on to point out that meteorological conditions affected pollution in two ways; first, in the way in which it was removed from the air of a city and, secondly, in its interaction with fog.

He based his account of the first effect largely upon the research conducted by Dr. Meetham at Leicester, which demonstrated the importance of the vertical removal of smoke and sulphur dioxide with its dependence on the degree of turbulence and the vertical lapse rate of temperature. The Leicester work showed clearly that the amount of smoke at street level increased from the windward side to the city centre and then decreased further down wind.

The theory was confirmed by the observations of the amount of daylight received in the city compared with outside, which showed a loss of daylight increasing down wind.

Sir Napier Shaw was the first to realise the importance of lapse rate on the matter when he pointed out that an inversion or " lid " would hold the smoke down. It had been difficult to correlate the Leicester smoke observations directly with upper air temperature owing to the nearest observations of the latter being made 70 miles away at Mildenhall and in the early morning, but Dr. Dobson showed curves of the connexion between Leicester pollution and the lapse rate observed over Mildenhall, demonstrating that the two are connected in the expected manner at low wind speeds but that in winds of over 20 m.p.h. there is sufficient turbulence to remove pollution upwards whatever the lapse rate.

Finally, there was the interaction between smoke and fog since the meteorological conditions favouring fog are precisely those opposing rapid removal of smoke. The smoke particles stick to the fog droplets and a dirty unpleasant fog is the result. An interesting point in this connexion is that Shaw and Owens found that London fogs which were " black " at 9 p.m. were clean at 5 a.m., which suggests the dirty fog droplets settle out during the night. In spite of this settling out, however, fogs may exist for several days. The temperature and humidity conditions in fog were not, he considered, sufficiently fully investigated to give a complete explanation of this phenomenon. Factors to be considered were the extension of cooling upwards as the top of the fog became the main radiating surface, the development of a lapse of temperature in the fog producing some degree of turbulence to bring down water droplets, and the reduction of the rate of evaporation in city fogs, when relative humidity fell below 100 per cent., by the solution of sulphur dioxide forming sulphurous acid which was rapidly oxidised to the very hygroscopic sulphuric acid.

LETTERS TO THE EDITOR

Artificial stimulation of rain formation

May I remark upon two points in Mr. J. K. Bannon's interesting article in the August issue of the *Meteorological Magazine* on " Artificial stimulation of rain formation."

The first concerns the temperature of −32·2° C. I do not wish to debate whether this is a critical temperature for the formation of ice crystals, but it is a matter of common flying experience that clouds certainly do not have to reach this temperature before moderate or heavy rain can occur. Indeed I think it is probably true to say that clouds, from which rain or snow is reaching the ground, more often than not nowhere have a temperature as low as −32 2 C.

The second concerns the calculations made of the order of magnitude of the heat changes in the experiment of February 5, 1947. According to Mr. Bannon's theory each particle of dry ice cools a thin streak of air to a temperature lower than −32 2 C. He then suggests that in the cooled streak of air seven eighths of the water is " quickly changed to ice." The latent heat thus released he computes to be sufficient to heat up this streak by 2 C. Thus, the streak having been previously cooled to below −32°C. the net result so far is a lowering of temperature in the cloud.

The ice crystals formed will, as Mr. Bannon states, soon leave these narrow streaks by precipitation or by diffusion, and will grow at the expense of supercooled water particles. They may even " infect some of the cloud below " and cause new ice crystals to form, though it is difficult to visualise such a process. But it does not seem likely that in any region, other than the originally-cooled streaks, there will be a change of seven eighths of the available water content to ice.

It is therefore not possible to say, without further data as to the number of ice crystals formed and as to their manner of growth, whether the latent heat released will, or will not, be sufficient to offset the original cooling.

RONALD FRITH

Royal Aircraft Establishment, Farnborough, Hants., January 12, 1948

[Dr. Frith may well be correct in saying that precipitating clouds do not necessarily have to extend to the −32 2 C. level. Cwilong's experiments* were carried out in conditions not strictly comparable with those in a growing cumulus cloud, and in my original article I indicated the doubtful validity of applying Cwilong's results to convective clouds. At the time of writing that article, however, Cwilong's figures were the only definite information available on the temperatures at which ice crystals form in saturated or supersaturated air. Since then further information has come to light† which indicates that ice crystals will begin to form in growing cumulus clouds at temperatures ranging from −6°C. for slowly growing clouds, to −20 C. for clouds with strong vertical currents. The important point is that a certain amount of cooling is required to form ice crystals in the supercooled water cloud.

In deriving the order of magnitude of possible heat changes due to the change in state from supercooled water to ice, I did not mean to imply that seven eighths of the supercooled water drops were changed to ice only in a " thin streak," but that the change took place through an appreciable volume of the cloud (the actual words used were " the top of the cumulus cloud ") and the net heating, calculated to raise the temperature by 2°C., would be spread over all this considerable volume of cloud and not over a thin isolated trail. The 300 lb. of " dry ice " used in the particular experiment under consideration would, in vaporising, cool only 70 cu. m. of cloud by just less than 1°C. There is little doubt, however, that a very much greater volume than 70 cu. m. was affected by the " dry ice " and so the net effect of the changes may well be a heating, since the cooling power of the granulated carbon dioxide is so small.

Alternatively, fixing the attention on a small streak of ice crystals as Dr. Frith does, though for their formation this small volume must initially have been cooled to some critical temperature (which may have been −32 2 C. or higher, it is not certain), it will soon have regained by ordinary eddy diffusion the general temperature of the surrounding air (very slightly lower, it is true,

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*CWILONG, B. M.; Sublimation in a Wilson chamber. *Proc. roy. Soc., London,* A, **190**, 1947, p. 137.

†See M.R.P. No. 361, 1947.

than before the sprinkling with " dry ice "), a fact perhaps overlooked by Dr. Frith; but the ice particles, once formed, will have remained and the process of change from supercooled water to ice must have gone on steadily, all the time releasing heat, until the ice particles fell because of their increasing size below the freezing level. The falling out of the crystals was, presumably, the only process which prevented the whole of the cloud from changing from supercooled water drops to ice. Not only was the heating effect of the change from water to ice probably much greater than the initial cooling by the carbon dioxide, but a large part of the heating must have been below the level of the initial cooling, since the ice crystals will have soon begun to fall. The neglect of the cooling effect of the carbon dioxide when calculating the order of magnitude of the heating by release of latent heat of fusion is therefore justified.—J. K. Bannon.]

Persistence of easterly winds

I was interested to read in " Weather of 1947 " in the February issue of the *Meteorological Magazine* the reference to the long spells of easterly wind.

Whilst at H.Q., 4 Group, York (1938-41) I was impressed by the frequency and marked persistency of easterly winds, and wondered whether this was normal. A preliminary and very rough investigation definitely indicated a progressive although irregular increase in the frequency of winds from the easterly quadrant during recent years. I did not follow up my investigation owing to pressure of work, but I do suggest that a detailed study of the airflow across the British Isles, using the observations from suitably selected stations for which observations over a long period are available, may well produce most interesting results and throw some light on a possible change of climate now taking place.

R. G. VERYARD

Organization of the Meteorological Service of Portugal

May I call your attention to an information given in the *Meteorological Magazine*, Vol. 76, 1947, p. 145, which is not entirely correct and therefore may lead to wrong conclusions.

The various meteorological services of Portugal in Europe and overseas were combined in August 1946 into a National Service, under the Prime Minister (now under the Minister for Communications), which is due to meet all the national needs in the fields of meteorology and geophysics. Since its organization, the National Service has had the responsibility for all the meteorological and geophysical activities in this country. There is no Naval Service which is independent of the National Service. Due to lack of personnel, some meteorological work is still carried out in the naval and other governmental departments, under the supervision of, and until it can be transferred to the National Service.

H. AMORIM FERREIRA

Servico Meteorologico Nacional, Lisbon, February 21, 1948

[To face p. 64

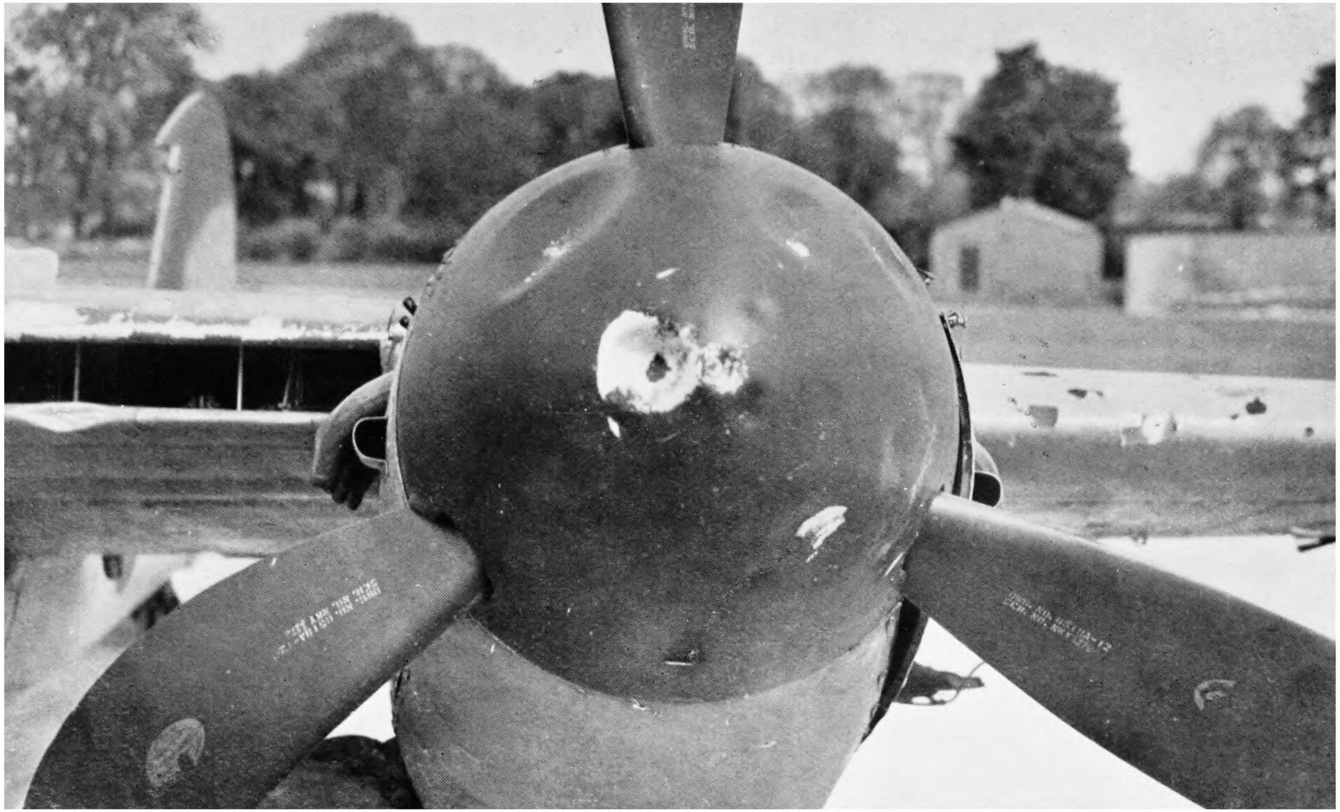

Photo by R.A.F.

HAIL DAMAGE TO PORT SPINNER OF MOSQUITO AIRCRAFT

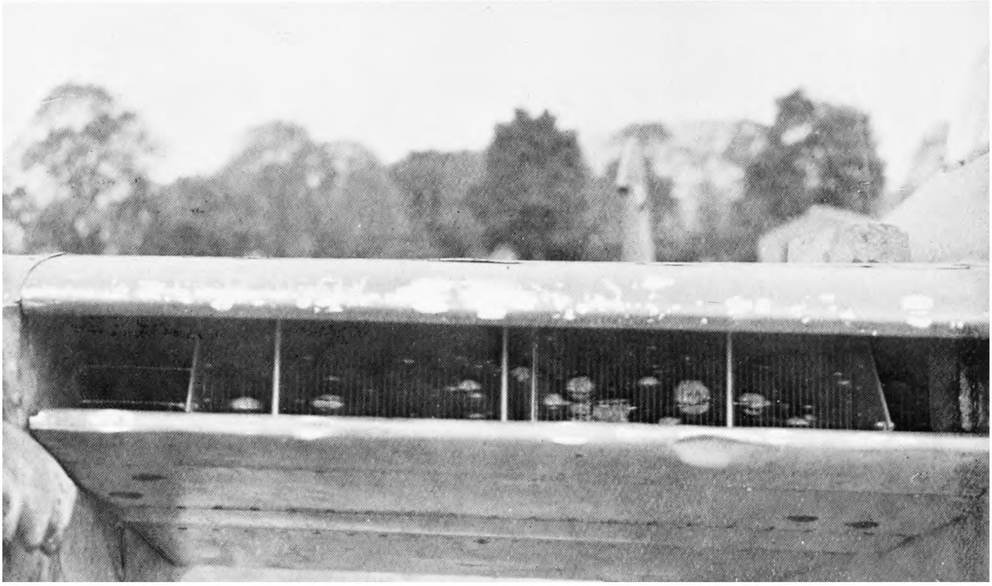

Photo by R.A.F.

HAIL DAMAGE TO RADIATOR OF MOSQUITO AIRCRAFT

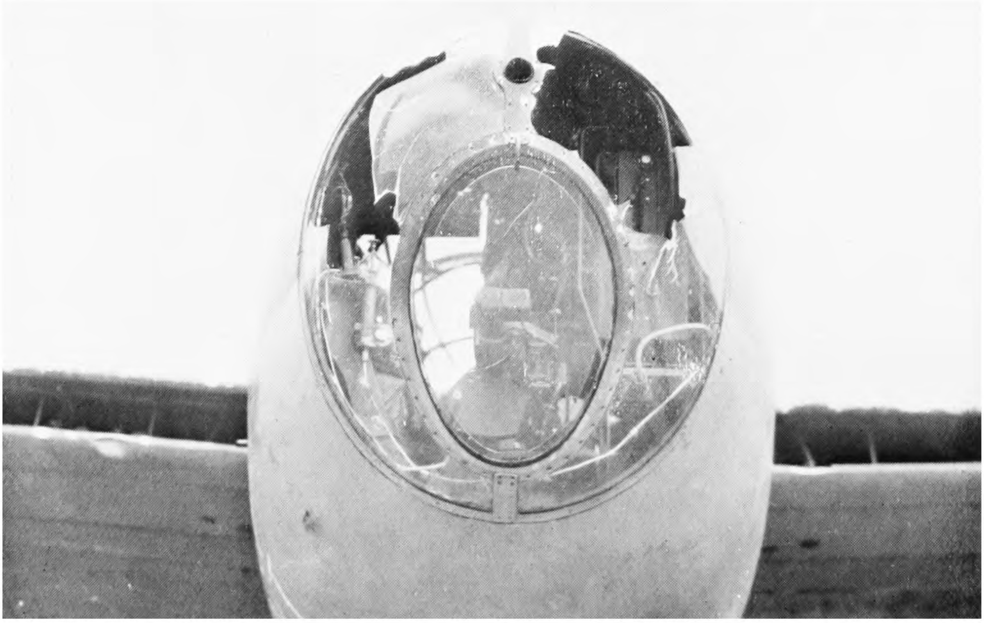

Photo by R.A.F.

HAIL DAMAGE TO MOSQUITO AIRCRAFT

NOTES AND NEWS

A Violent Hailstorm in Oxfordshire on May 11, 1945

A notable hailstorm occurred in the south Midlands area in the evening of May 11, 1945. An account in the local (Oxford) Press referred to hailstones at least one inch in diameter, one of which weighed 2 oz. F/Lt. J. M. Edmonds, then of the Meteorological Office, R.A.F., Winslow, witnessed the storm at Bicester, and he compared the size of the hailstones to that of golf balls. F/Lt. Rigby of the same headquarters estimated a diameter of about an inch for some of the stones which fell at Padbury near Buckingham.

The quantity of water resulting from the rapid melting of the hailstones was so great as to render one of the airfields in the Oxford area unserviceable for a time. The local Press reports stated that there was extensive damage to windows, greenhouses and crops. One report said that the fall of hail was preceded by a peculiar noise in the sky like glass being broken.

A " Mosquito " aircraft from Barford St. John engaged on a local exercise flew into the storm and was severely damaged by hailstones. Holes were torn in the wings, the spinners were badly dented and the honeycomb radiators seriously damaged. The dents in the very strong honeycomb radiators measured 2 in. to 2½ in. across, and the holes in the leading edges of the wings were roughly 2 in. square with some approximately 4 in. by 3 in.

The pilot stated that on returning to base at a height of about 10,000 ft. he found large cumulonimbus cloud in the neighbourhood and decided to descend through a gap. At 5,500 ft. he found the aircraft being drawn into cloud, and after an estimated time of 30 sec. in the cloud he broke cloud at 4,000 ft. The aircraft was thrown about rather violently, and presumably turned over as the navigator's pockets were emptied of money. The direct result of the damage was to increase the stalling speed necessitating landing at a higher speed than usual, as a result of which the aircraft overshot the airfield, but fortunately there was no serious injury to pilot or navigator.

The storm was first reported south of Oxford and travelled almost due north reaching its climax at Kidlington between 1630 and 1715 G.M.T.

A depression to the south-west of the Bay of Biscay was filling up slowly and was surrounded by unstable air. The surface pressure gradients over southern England were rather weak, the low-level winds being mainly south-easterly about 15 kt. The upper winds veered to southerly about 20 kt. at 6,000 ft. and south-south-westerly at higher levels increasing to about 40 kt. at 20,000 ft.

Inspection of the upper air temperatures from the Larkhill radio-sondes on May 11 showed that a surface temperature of about 79°F. would suffice to initiate convection clouds extending to very high levels. Such temperatures were realised over central southern England by about 1500 G.M.T., while the falls of pressure during the afternoon resulted in the formation of a small heat low in this area. The storms broke out at about 1600 G.M.T.

OBITUARY

F/Lt. G. R. Mason, B.Sc. We report with deep regret the death of F/Lt. G. R. Mason who served in the Meteorological Branch, R.A.F.V.R., from 1939 to 1945. F/Lt. Mason graduated at the University of Leeds in 1927 with first-class honours in Mathematics and joined the examining staff of the Patent Office.

He volunteered for the Meteorological Branch of the R.A.F.V.R. on its formation in the summer of 1939 and was called up for training following the outbreak of war in September.

F/Lt. Mason was a forecaster for periods at H.Q.2 and H.Q.3 Group but the greater part of his service was rendered overseas. He was with H.Q. Air Component in France before Dunkirk and again in France with the special unit near Marseilles between Dunkirk and the French armistice. He was posted to Aden in December 1940 and was there and elsewhere in the Middle East until May 1944. He was demobilised in October 1945 and returned to his duties at the Patent Office.

F/Lt. Mason always gave of his best and earned the high opinion of his colleagues for his ability, devotion to duty and sportsmanship.

He leaves a widow and two sons to whom we offer our deepest sympathy.

REVIEWS

Long-range weather forecasts in the Netherlands. By S. W. Visser. Koninklijk Nederlandsch Meteorologisch Instituut No 102, Mededeelingen en Verhandelingen 51. 8vo. 9½ in. × 6¾ in., pp. 143, *Illus.* 's Gravenhage 1946. 0.40 florins. Dutch with English summary.

As soon as he exceeds the period for which "extended range" inferences can be made from the daily synoptic chart, the forecaster finds himself in great difficulties. The possible factors affecting the weather of, for example, western Europe, are so many, and their connexions so obscure, that reasoning from cause and effect in physical processes breaks down, and must be replaced by groping in a dimly-lit maze of statistics. The process is very laborious; the investigation of the possibility of monthly forecasts of temperature and precipitation in Holland has occupied Dr. S. W. Visser for ten years.

He has two lines of attack; periodicities and correlation. Among the periodicities investigated are 2¼, 3, 3¼, 5¼, 6·8–7, 7½, 8, 9, 11, 13 and 35 years, but of these only the first is found to be of any practical use; the others being either non-existent or too weak and irregular. In particular the author finds that a 3-year cycle often boils down to the fact that in a random series the average interval between maxima (or minima) is precisely 3 units. It must be remarked that the plot of even the 2¼-year cycle, Fig. 3, is far from convincing! The 2¼-year and 5¼-year cycles are both found to be widespread over the North Atlantic; the former crosses the ocean in 6–7 months, the latter in 11 years. On the basis that this ratio of 1 : 20 is also the ratio of the speeds of ocean and wind currents, he concludes that the former is wind-borne and the latter water-borne, but surely the Gulf Stream does not take 11 years to cross the Atlantic ! Actually it takes 6–7 months, so that the 2¼-year cycle is the more likely to be water-borne. All the work on cycles seems to the reviewer to be rather uncritical; a systematic periodogram analysis would have been more satisfactory.

The practical results of the investigation are due mainly to the extraordinarily thorough work on correlation. Rainfall of Holland and temperature at De Bilt were correlated month by month with 17 other variables, with lags of one to 12 months—144 coefficients for each combination of two variables. When the significant coefficients have been selected, their interrelations still have to be eliminated by partial correlation. Eventually eleven factors are selected as the basis of regression equations; these are: rainfall at Paramaribo, temperature at Ivigtut and De Bilt, pressure at Ponta Delgada, Reykjavik, Helsinki and Berlin, pressure difference Ponta Delgada-Reykjavik and Berlin-Helsinki, variability of sunspots and the 2¼-year cycle. It is noteworthy that the effect of Arctic ice is not included; the author appears to be unaware of the extensive work done in the British Meteorological Office about 1928 on this important factor.

Each regression equation contains five or six of these eleven independent variables and the " multiple correlations " between computed and observed values of rainfall range from 0·705 to 0·847, and of temperature from 0·694 to 0·845.

These final results seem at first sight to be very satisfactory, but on consideration doubt creeps in. To begin with, the effective measure of the part played by one variable in the irregularity of another is not the correlation coefficient between them but its square, so that the real measure of success ranges from less than three quarters to less than half. More serious is the fact that the regression equations are based on the highest coefficients selected from a very large number, apparently solely on the criterion of magnitude. The author examines their relation to their probable errors, but he calculates the latter by the expression for coefficients of zero order, overlooking the fact that the effective number of observations decreases by one for each step in partial correlation. As there are only 39 observations to begin with, this increases the probable errors considerably. It is almost certain that several of the relationships used in the regression equations are due to chance or are much smaller than the coefficients suggest. This point may be illustrated by the coefficients of sunspot variability in January with rainfall 5, 6, 7, 8 and 9 months later: + ·16, − ·40, + ·26, − ·48, + ·04. The two negative coefficients are regarded as highly significant and used in the forecasting equations, but to the reviewer they seem merely the results of chance !

The author claims considerable success for " forecasts " obtained by comparing the observed and calculated values for the period investigated (1901–39). This, however, means little; in such a test a temporary agreement arising by chance will appear just as good as a real permanent relationship. The real test comes when the equations are applied to years outside the period on which they are based. The author made two such tests: of 1881–1900 he says " The success was not in all respects satisfying, the number of failures being too large. The cause of this result is due to the climate break of Schmauss." For 1940–4 on the other hand he claims much greater success. Table LXX gives the results of 15 comparisons, of which eight were successful, one partially successful and six failed. The criterion of success is that the forecast value differs from the observed by less than the standard deviation of the latter; with such a criterion a forecast of " normal conditions " would succeed two times out of three. The signs of the forecast and observed deviations agreed on eight occasions and differed on seven.

This account of a very painstaking research may appear to be unduly critical, but the criticisms are meant in a helpful spirit. It is by such patient work that progress is made, and the basis laid down for greater success in the future.

C. E. P. BROOKS

A method for determining the daily variation in width of a shadow in connection with the time of the year and the orientation of the overshadowing object. By R. J. v. d. Linde and J. P. M. Woudenberg. Koninklijk Nederlandsch Meteorologisch Instituut. No. 102, Mededeelingen en Verhandelingen 52. 8vo, 9½ in. × 6¾ in., pp. 7. *Illus.* 's Gravenhage, 1946. 0.40 florins. Dutch with English summary.

This publication contains diagrams giving a neat and rapid solution to the problem of finding the breadth of shadow cast by a straight hedge on to level ground. If as seen from a point on the shadow edge the altitude of the sun is α and the angle between the normal to the hedge and the bearing of the sun is β then the ratio S/h of breadth of shadow to height of hedge is equal to $\cot\alpha\cos\beta$

Two diagrams are necessary. The first of these has a grid with altitude of the sun as ordinate and azimuth of the sun as abscissa measured east and west from the south point both on a scale of 5 per cm. Traced on this grid are the tracks of the sun as seen from the latitude of Amsterdam for the 20th or 21st of each month and isopleths of time for every half hour. Separate diagrams are needed for the first and second halves of the year because of the difference in the equation of time.

The second diagram, printed on transparent paper, has a grid on the same scale as the first with altitude as ordinate and azimuth as abscissa, and carries isopleths of the values of S/h ranging from 8/1 to 1/16. It is symmetrical about the central vertical line.

If now the breadth of shadow of a hedge, such that the normal to it drawn towards the south has azimuth A, is required the second diagram is placed on the first so that the bases coincide and the mid point of the base of the second is on the point AO of the first. Thus, in the case of a hedge extending from north-west to south-east the second diagram would be placed with the mid point of its base on the point azimuth 45 west of south on the base of the first diagram. The date and time are pinpointed on the first diagram and the ratio S/h read off between the isopleths on the second one.

Over most of the first diagram the isopleths of months and half hours form a roughly rectangular grid of sides about 1 5 by 2 cm. It should be possible to pinpoint the sun's position within a degree in both altitude and azimuth even though the scales are by no means linear in date and time.

It would have been useful if the authors had provided a statement of the error which might occur in the estimation of the final result consequent on a small error in pinpointing the date and time. A little algebra shows that fortunately the errors are least when the sun is high in the sky and exactness is most necessary.

G. A. BULL

ERRATUM

January 1948, page 11, equation (6)

for $$\frac{H}{H} = -\left(a + \frac{bH}{2}\right)$$

read $$\frac{\delta H}{H} = -\left(a + \frac{bH}{2}\right)$$

WEATHER OF JANUARY, 1948

Unsettled conditions prevailed throughout the month with depressions or troughs of low pressure passing over or near the British Isles. The mean pressure for the month (Fig. 1) showed a deep depression centred south of Iceland and extending from south Greenland to Norway and southward to the English Channel. Pressure at the centre was below 990 mb. An anticyclonic belt, pressure over 1020 mb., extended from south-west of the Azores to Gibraltar; 1020 mb. was exceeded also over much of the eastern United States and the Great Lakes. Pressure was below the average (Fig. 2) from the West Indies across the Atlantic and Europe to Russia, and slightly above the average over the eastern states of North America and Canada as well as north of the Arctic Circle and in the neighbourhood of Madeira. The deficiency was greatest over the central area of the British Isles where it amounted to approximately 20 mb. The nearest approach to the distribution of the deviations from

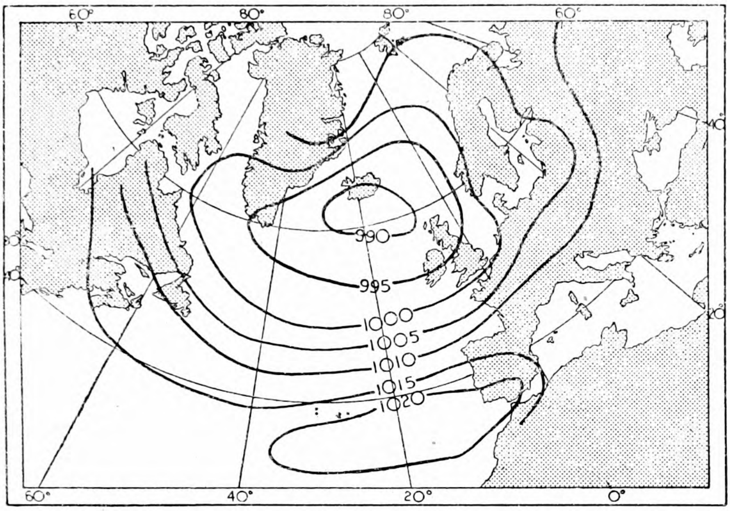

FIG. 1—MONTHLY MEAN PRESSURE, JANUARY 1948

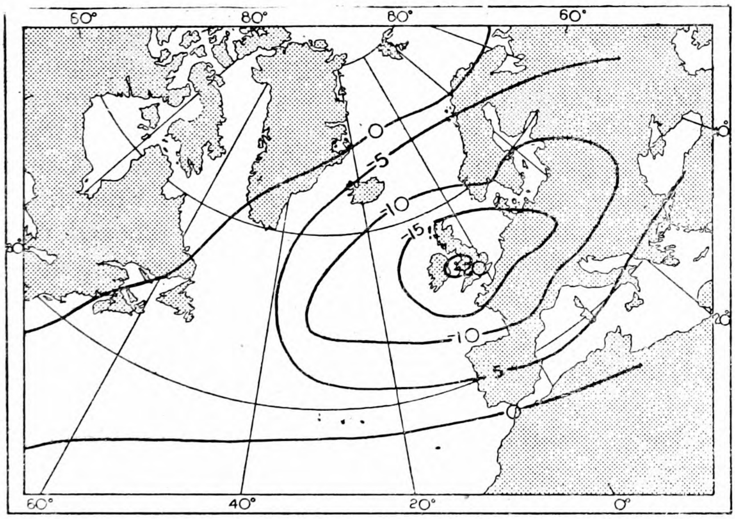

FIG. 2—PRESSURE DIFFERENCES FROM NORMAL, JANUARY 1948

normal pressure that could be found occurred as long ago as January 1930, the chart for which month is given in Fig. 3.

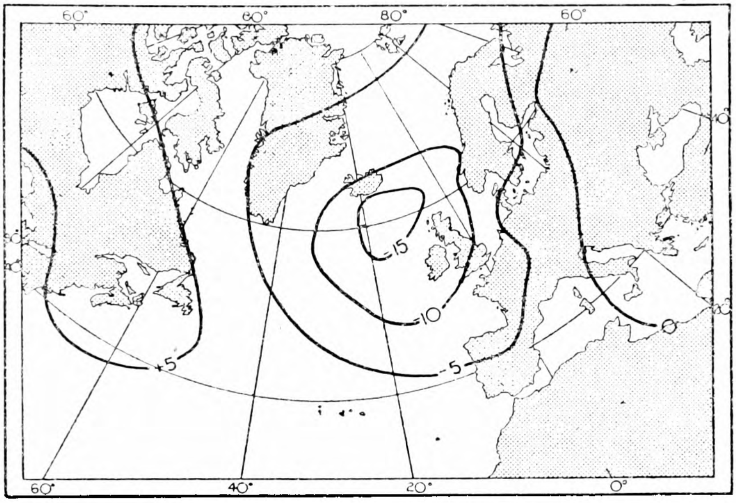

FIG. 3—PRESSURE DIFFERENCES FROM NORMAL, JANUARY 1930

In the British Isles the weather was very unsettled and excessively wet, with frequent strong winds and local gales. Mean pressure was exceptionally low; at such widely separated stations as Oxford and Southport it was the lowest on record for any month. In Scotland and Northern Ireland the weather was cold but in England and Wales it was generally rather mild. The deviation from the average temperature ranged from −2·4°F. in north Scotland to +3·3°F. in south-east England. The extreme temperatures for the month were 60 F. at Cannington, Somerset on the 3rd and 4°F. at Logie Coldstone, Aberdeenshire on the 24th. The general rainfall was exceptionally heavy, particularly in England and Wales where it was the wettest January in a record which goes back to 1869. Local snow or sleet showers occurred frequently from the 5th—28th. In Scotland, moderate snowfall occurred in Caithness on the 9th and more generally on the 17th—18th; snow lay to a depth of from six to nine inches in places and drifts five to six feet deep blocked main roads in central districts. Local thunderstorms were rather frequent for the time of year. The month was stormy, with frequent strong winds and gales; a mean hourly velocity of more than 38 m.p.h. was measured at the anemometer stations at St. Ann's Head and St. Mary's, Scilly on as many as 15 days and 13 days respectively.

The general character of the weather is shown by the following table :—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	60	21	+2·0	234	+8	80	15
Scotland	55	4	−1·7	162	+3	82	14
Northern Ireland ..	55	21	−1·3	196	+5	95	17

RAINFALL OF JANUARY 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	3·61	194	*Glam.*	Cardiff, Penylan ..	8·56	232
Kent	Folkestone, Cherry Gdns.	3·87	172	*Pemb.*	St. Ann's Head.. ..	7·32	210
,,	Edenbridge, Falconhurst	4·78	195	*Card.*	Aberystwyth	5·13	159
Sussex	Compton, Compton Ho.	7·54	237	*Radnor*	Bir. W. W., Tyrmynydd	15·75	250
,,	Worthing, Beach Ho. Pk.	4·74	203	*Mont.*	Lake Vyrnwy	17·74	320
Hants.	Ventnor, Roy. Nat. Hos.	6·40	249	*Mer.*	Blaenau Festiniog ..	24·07	235
,,	Fordingbridge, Oaklands	5·75	208	*Carn.*	Llandudno	5·80	241
,,	Sherborne St. John ..	6·04	260	*Angl.*	Llanerchymedd ..	8·52	270
Herts.	Royston, Therfield Rec.	3·49	202	*I. Man.*	Douglas, Boro' Cem. ..	10·89	325
Bucks.	Slough, Upton	4·09	220	*Wigtown*	Port William, Monreith	7·63	233
Oxford	Oxford, Radcliffe ..	5·01	277	*Dumf.*	Dumfries, Crichton R.I.	7·43	231
N'hant	Wellingboro', Swanspool	3·79	205	,,	Eskdalemuir Obsy. ..	10·24	190
Essex	Shoeburyness	2·71	201	*Roxb.*	Kelso, Floors	6·04	345
Suffolk	Campsea Ashe, High Ho.	3·41	187	*Peebles.*	Stobo Castle	6·84	228
,,	Lowestoft Sec. School ..	3 69	264	*Berwick*	Marchmont House ..	7·08	315
,,	Bury St. Ed., Westley H.	4·29	240	*E. Loth.*	North Berwick Res. ..	5·44	316
Norfolk	Sandringham Ho. Gdns.	4·06	209	*Midl'n.*	Edinburgh, Blackf'd. H.	5·27	299
Wilts.	Bishops Cannings ..	5·95	256	*Lanark*	Hamilton W. W., T'nhill	6·17	187
Dorset	Creech Grange ..	6·85	210	*Ayr*	Colmonell, Knockdolian	7·40	171
,,	Beaminster, East St. ..	7·87	226	,,	Glen Afton, Ayr San. ..	10·27	201
Devon	Teignmouth, Den Gdns.	6·59	226	*Bute*	Rothesay, Ardencraig ..	7·14	159
,,	Cullompton	7·86	243	*Argyll*	L. Sunart, Glenborrodale	8·50	120
,,	Barnstaple, N. Dev. Ath.	5·90	180	,,	Poltalloch	7·01	139
,,	Okehampton, Uplands	10·86	213	,,	Inveraray Castle ..	11·90	145
Cornwall	Bude School House ..	6·44	212	,,	Islay, Eallabus	8·22	176
,,	Penzance, Morrab Gdns.	7·96	210	,,	Tiree	6·57	155
,,	St. Austell, Trevarna ..	9·45	221	*Kinross*	Loch Leven Sluice ..	5·72	182
,,	Scilly, Tresco Abbey ..	5·96	190	*Fife*	Leuchars Airfield ..	4·07	224
Glos.	Cirencester	5·09	203	*Perth*	Loch Dhu	11·25	124
Salop	Church Stretton ..	5·76	221	,,	Grieff, Strathearn Hyd.	5·31	133
,,	Cheswardine Hall ..	5·44	246	,,	Blair Castle Gardens ..	4·73	142
Staffs.	Leek, Wall Grange, P.S.	5·74	199	*Angus*	Montrose, Sunnyside ..	3·85	193
Worcs.	Malvern, Free Library	4·80	217	*Aberd.*	Balmoral Castle Gdns...	3·71	134
Warwick	Birmingham, Edgbaston	4·52	224	,,	Dyce, Craibstone ..	4·70	199
Leics.	Thornton Reservoir ..	4·31	218	,,	Fyvie Castle	2·87	121
Lincs.	Boston, Skirbeck ..	3·76	232	*Moray*	Gordon Castle	1·24	61
,,	Skegness, Marine Gdns.	3·53	204	*Nairn*	Nairn, Achareidh ..	2·10	116
Notts.	Mansfield, Carr Bank ..	5·04	234	*Inv's*	Loch Ness, Foyers ..	3·95	94
Ches.	Bidston Observatory ..	5·73	270	,,	Glenquoich	13·28	97
Lancs.	Manchester, Whit. Park	7·37	294	,,	Fort William, Teviot ..	7·95	82
,,	Stonyhurst College ..	8·80	206	,,	Skye, Duntuilm ..	5·65	107
,,	Blackpool	6·99	256	*R. & C.*	Ullapool	4·81	108
Yorks.	Wakefield, Clarence Pk.	5·40	281	,,	Applecross Gardens ..	5·46	100
,,	Hull, Pearson Park ..	4·26	237	,,	Achnashellach	9·41	103
,,	Felixkirk, Mt. St. John	5·66	283	,,	Stornoway Airfield ..	5·45	111
,,	York Museum ..	4·73	267	*Suth.*	Lairg	5·58	170
,,	Scarborough	4·56	228	,,	Loch More, Achfary ..	9·98	137
,,	Middlesbrough.. ..	5·48	342	*Caith.*	Wick Airfield	3·95	161
,,	Baldersdale, Hury Res.	8·42	259	*Shet.*	Lerwick Observatory ..	4·79	112
Nor'ld	Newcastle, Leazes Pk.	8·01	404	*Ferm.*	Crom Castle	6·29	189
,,	Bellingham, High Green	8·51	298	*Armagh*	Armagh Observatory ..	6·72	267
,,	Lilburn, Tower Gdns. ..	7·21	348	*Down*	Seaforde	8·58	272
Cumb.	Geltsdale	7·48	267	*Antrim*	Aldergrove Airfield ..	5·61	205
,,	Keswick, High Hill ..	9·63	191	,,	Ballymena, Harryville	6·19	167
,,	Ravenglass, The Grove	7·96	238	*Lon.*	Garvagh, Moneydig ..	5·34	155
Mon.	Abergavenny, Larchfield	8·51	252	,,	Londonderry, Creggan	5·86	163
Glam.	Ystalyfera, Wern House	13·73	217	*Tyrone*	Omagh, Edenfel ..	5·20	147

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, SEPTEMBER 1947

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily Mean	Per-centage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1018·7	+1·5	77	40	68·9	52·5	60·7	+3·2	57·1	77	6·9	1·17	−0·70	10	5·2	41
Gibraltar	1017·1	−0·1	84	61	80·4	67·8	74·1	+1·7	69·5	82	4·9	1·07	—	2	—	—
Malta	1016·4	+0·1	88	63	83·1	70·2	76·7	+0·7	72·5	68	3·4	0·24	—	3	9·3	75
St. Helena	1018·5	—	67	51	60·5	52·7	56·6	−0·3	53·1	98	9·7	4·93	+2·68	25	—	—
Freetown, Sierra Leone	1012·9	+2·3	87	71	83·3	74·4	78·9	+1·6	75·3	89	8·6	30·01	+1·53	27	4·0	33
Lagos, Nigeria ..	1013·4	+1·2	88	68	84·0	71·0	77·5	−1·2	74·9	88	9·2	7·50	—	22	2·9	24
Kaduna, Nigeria ..	1012·0	—	90	63	84·3	66·5	75·4	−0·5	70·9	81	8·4	6·96	−4·54	18	5·3	43
Chileka, Nyasaland																
Salisbury, Rhodesia..																
Cape Town ..	1020·3	+1·2	82	41	67·6	52·0	59·8	+1·9	52·9	74	5·9	1·35	−0·89	9	—	—
Germiston, South Africa	1019·2	—	83	38	72·2	48·3	60·3	—	47·5	45	2·5	0·41	—	7	9·1	77
Mauritius																
Calcutta, Alipore Obsy.	1004·3	−0·2	96	76	90·7	79·6	85·1	+1·9	79·9	90	7·9	14·00	+3·99	18	5·0	41
Bombay	1006·0	−2·0	89	68	85·4	76·6	81·0	+0·1	76·4	90	8·3	25·45	+14·77	25	3·2	26
Madras	1005·9	−0·6	99	72	91·8	76·8	84·3	−0·9	75·8	78	8·2	5·33	+0·48	12	5·4	44
Colombo, Ceylon ..	1010·3	+0·4	87	73	84·2	76·1	80·1	−1·1	75·5	85	8·8	7·31	+2·55	13	5·4	44
Singapore	1009·5	−0·3	91	71	87·3	74·4	80·9	−0·2	78·3	87	—	10·83	+4·04	15	—	—
Hongkong	1009·5	+1·2	92	73	85·6	77·0	81·3	+0·3	77·3	85	—	17·70	+8·01	21	5·6	45
Sydney, N.S.W. ..	1018·7	+2·6	82	42	68·3	51·2	59·7	+0·5	53·1	62	5·0	0·77	−2·09	6	8·0	67
Melbourne	1017·0	+1·2	76	35	62·9	45·1	54·0	−0·1	48·9	66	7·2	2·20	−0·24	17	4·7	40
Adelaide	1018·7	+1·2	82	41	64·3	47·6	55·9	−1·3	50·3	60	5·9	1·85	−0·23	12	5·5	47
Perth, W. Australia	1019·5	+1·5	79	39	67·0	47·5	57·3	−0·9	53·1	62	4·0	3·19	−0·23	15	7·7	65
Coolgardie	1019·7	+2·5	88	36	72·5	45·7	59·1	+0·4	48·5	53	2·1	0·61	−0·06	5	—	—
Brisbane	1019·5	+1·9	81	47	74·0	56·5	65·3	+0·1	58·5	64	5·2	2·93	+0·93	13	6·9	58
Hobart, Tasmania ..	1010·9	−0·1	73	35	60·0	42·3	51·1	+0·1	45·2	61	6·8	1·63	−0·44	9	6·6	56
Wellington, N.Z. ..	1014·6	0·0	64	36	56·6	44·8	50·7	+0·6	48·2	76	7·1	5·49	+1·52	13	5·9	50
Suva, Fiji	1015·1	+0·8	84	65	79·5	70·0	74·7	+0·2	71·1	82	7·7	8·55	+0·86	22	4·5	37
Apia, Samoa ..	1012·5	+0·3	89	70	86·3	74·0	80·1	+1·9	76·7	76	5·5	10·23	+5·12	20	8·0	67
Kingston, Jamaica ..	1013·4	+1·2	94	71	87·7	74·7	81·2	−0·3	75·8	78	4·7	10·31	+6·28	13	7·6	62
Grenada, W. Indies	1012·8	+1·0	88	72	87·1	75·9	81·5	+1·2	78·1	79	6·3	6·06	−1·93	26	—	—
Toronto	1019·9	+2·1	87	34	72·7	53·8	63·3	+3·0	55·1	82	3·6	1·79	−0·88	8	7·1	57
Winnipeg	1015·8	+2·0	88	21	64·4	41·9	53·1	−0·6	42·0	87	5·2	0·85	−1·37	11	5·5	43
St. John, N.B. ..	1020·1	+2·7	82	34	65·7	49·9	57·8	+1·9	52·6	86	5·9	2·21	−1·53	10	6·4	51
Victoria, B.C. ..	1018·2	+1·8	78	36	68·2	46·4	57·3	+1·2	48·3	90	3·3	1·15	−0·66	7	7·6	60

M.O. 501 AIR MINISTRY

METEOROLOGICAL OFFICE

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PRESSURE-PATTERN FLYING

BY J. S. SAWYER, M.A.

During the recent war several developments took place in aviation, which led to an increased importance to the air navigator of the close relation between atmospheric pressure and wind. As a result, several methods of navigation and flight planning have been developed which have come to be known under the general title of " pressure-pattern flying ".

The most important of the factors which led to the development of " pressure-pattern flying " were, first the development of the radio altimeter, secondly the increase of long-distance transoceanic flying, and thirdly the increase in the average airspeed, and on the meteorological side the improved network of upper air soundings which permitted the accurate delineation of pressure systems at several levels in the atmosphere.

The pulse-type radio altimeter provides a reasonably accurate measurement of the true height of the aircraft above the surface beneath. Moreover, the pressure altimeter, which an aircraft also carries and which is essentially an aneroid barometer, can be used to measure the atmospheric pressure at the flight level. Thus by comparing the readings of pressure and radio altimeters when flying above a surface of known height such as the sea or a large lake, the navigator is provided with a measure of the atmospheric pressure at a known height. Successive observations enable him to measure the pressure gradient in the direction in which he is flying, and, since it is known that the component of the wind in a perpendicular direction is very closely related to this gradient, the navigator thus has a means of estimating his drift. The high airspeed enables him to ignore the pressure changes taking place during the flight.

The planning of long transoceanic flights where there were no land marks or intermediate airfields also drew attention to the fact that the geographically shortest route is not always the best or even the quickest. Thus out of attempts to improve on the direct route has grown the technique of " single heading flight " and other methods of pre-flight planning intended to reduce the duration of flight. The primary intention is not to get to the destination sooner, but to reduce the fuel load which must be carried and thereby to increase the pay load. Single heading flight also has the advantage that a course can be calculated on the basis of pressure observations or forecasts at the terminals alone, and the navigator is thus not dependent on wind information over the intermediate regions from which it may not be available. Single heading flight has also been employed to reduce the navigational work necessary in the air by the pilot-navigator of a fast single-seater aircraft.

The basic theory of both altimetric drift determination and single heading flight may be understood by reference to Fig. 1.

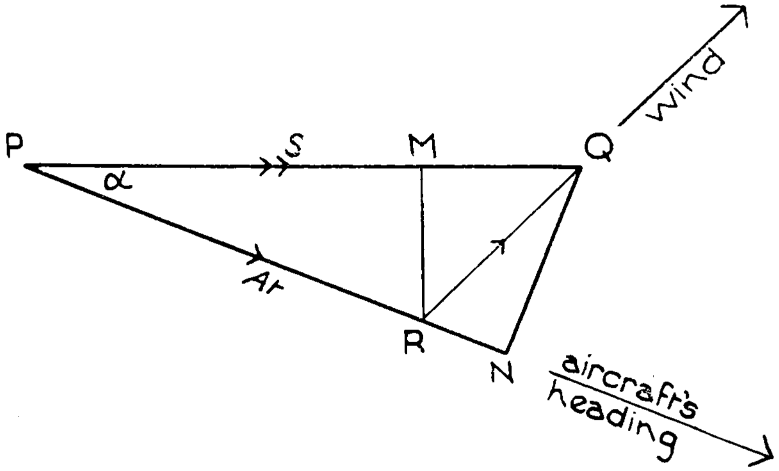

FIG. 1

We consider an aircraft flying on a constant geographical course (constant heading) along an isobaric surface (i.e. with a constant height as indicated by the pressure altimeter) and at a constant airspeed, A.

We consider the progress of the aircraft over a short section of its track PQ (Fig. 1). PR ($= At$) represents the displacement which the aircraft would have had in still air in the interval t taken to fly from P to Q; RQ represents the displacement due to wind in the same interval, resulting in the net displacement PQ ($= S$). In Fig. 1, also, NQ represents the component of the displacement due to wind in a direction perpendicular to the aircraft's heading, and we denote this by Z; RM represents the displacement due to wind in a direction perpendicular to PQ, and is equal to vt where v is the component of wind perpendicular to PQ.

Since triangles PNQ and PMR are similar,

$$\frac{QN}{PQ} = \frac{RM}{PR}$$

and thus

$$\frac{Z}{S} = \frac{vt}{At} \qquad \text{.. (1)}$$

It is well known that, except near the equator, the wind is closely related to the pressure gradient by the geostrophic wind relation which requires that it blows in the direction of the isobars (or contours of an isobaric surface) with a speed proportional to the pressure gradient. Expressed in terms of the slope of the isobaric surface on which the flight is conducted, this relation may be expressed as

$$V = \frac{g}{2\omega \sin \phi} \frac{H_Q - H_P}{S} \quad \cdot\cdot \quad (2)$$

where g is the acceleration due to gravity

ω is the angular velocity of the earth

ϕ is the latitude

and H_P, H_Q are the heights of the isobaric surface at P and Q.

By combining equations (1) and (2) we obtain the relation

$$Z = \frac{g}{2\omega \sin \phi} \frac{H_Q - H_P}{A} \quad \cdot\cdot \quad (3)$$

If now we write the difference between the readings of the radio altimeter and the pressure altimeter (radio altimeter minus pressure altimeter) as D_1, and D_2 at P and Q respectively, it follows that $H_Q - H_P = D_2 - D_1$, because the pressure altimeter has the same reading at P and Q. This value D is known as the " altimeter correction ".

Equation (3) may then be written in the navigator's usual units (nautical miles for Z, knots for A and feet for D_2 and D_1) as

$$Z = \frac{21 \cdot 47}{\sin \phi} \frac{D_2 - D_1}{A} \quad \cdot\cdot \quad (4)$$

This is the fundamental equation of pressure-pattern flying, since it enables the navigator to calculate his drift from readings of his pressure and radio altimeters. If D, the difference between their readings as defined above, is increasing along his track, his drift is to port in the northern hemisphere, and if decreasing, to starboard. In the southern hemisphere the rule is reversed.

Equation (4) is not only true over a short distance PQ for which we have demonstrated it above; it can equally be applied to a long flight as can readily be shown by integration of equation (4) over the aircraft's track. Provided that the aircraft's course (heading) and airspeed remain constant, the equation gives a method of calculating the total drift (and thus the course to be flown) from the values of D at the terminals only. It is in this manner that it is applied to calculate the course to be flown on a single heading flight.

Although the aircraft's course is maintained constant its track is not a straight line, because the effect of the wind is different over different parts of the route. This is illustrated in Fig. 2, in which the track which would be followed on a single heading flight is shown in conjunction with the pressure distribution on a particular occasion.

When the durations of flights made by single heading methods are compared with those which would have been made on the same occasions by conventional navigation, it is found that the single heading flight plan often results in a quicker flight.

However, it is important to realise that a single heading flight plan does not usually give the most economical flight possible, even at the level at which it is conducted. Under certain circumstances it may even result in a longer duration of flight than a flight along the great circle.

Attention has therefore been directed to methods of choosing the most economical flight path. This is a problem which is still unsolved, and will

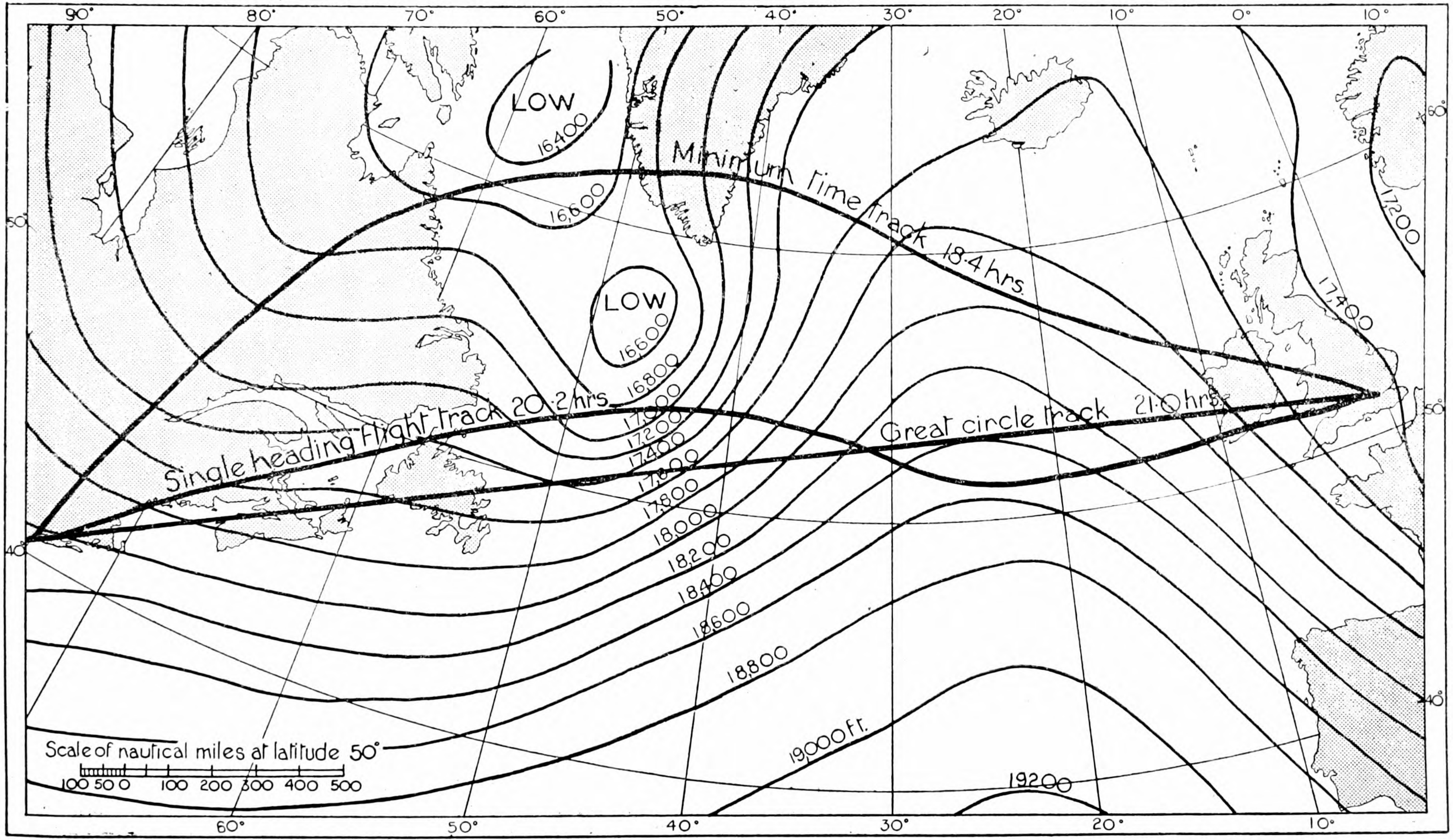
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
10°
LOW
16400
16600
LOW
16600
16800
17000
17200
17400
17600
17800
18000
18200
18400
18600
18800
19000 ft.
19200
17200
17400
Minimum Time Track 18·4 hrs.
Single heading flight Track 20·2 hrs.
Great circle Track 21·0 hrs.
Scale of nautical miles at latitude 50°
100 50 0 100 200 300 400 500
60°
50°
40°
30°
20°
10°
50°
40°
60°
50°
40°

FIG. 2—CONTOURS OF THE 500-MB. SURFACE AT 0400 TO 0600 G.M.T., DECEMBER 4, 1946

This chart also shows the minimum-time track and single-heading flight track for an aircraft leaving London for New York at 0200 G.M.T. with airspeed 200 kt. and flying on the 500-mb. surface. In computing the tracks shown allowance has been made for the changes taking place in the pressure distribution.

always involve a compromise between many factors, such as the fuel economy, the weather expected, the reliability of the forecast, the location of intermediate airfields and many others. However it is interesting to note that many aircraft are now routed across the Atlantic on tracks which take them considerable distances from their direct route, and thereby they reach their destination sooner or obtain better weather.

To demonstrate this Fig. 2 also includes the flight track which would give the least time of any at about the 20,000-ft. lèvel on the occasion for which the pressure distribution is illustrated. By passing north of the active depression an aircraft following this track would avoid the strong head winds further south, and with an airspeed of 200 kt. would reach New York from London with a saving of more than 2 hrs. over a flight along the great circle.

In conclusion it must be pointed out that in deriving the relations which form the basis of single heading flight and altimetric drift determination, several assumptions are made which are not strictly valid. In particular it is assumed that the wind is in accordance with the geostrophic wind equation; a condition which is known not to be strictly fulfilled. The results of the application of the formulae are thus only approximate; but both theoretical consideration and flight trials have shown that the relations are sufficiently close to provide the air navigator with a useful tool, comparable in accuracy with the others at his disposal.

SOME ASPECTS OF THE THEORY OF TURBULENCE

E. J. SUMNER, B.A.

Part I

The phenomenon of turbulent motion is one of everyday occurrence, and like other commonplace experiences it is one that is extremely difficult to define. Owing to the indescribable complexity of the motion it is little wonder that all definitions evade the issue, and either refer to the circumstances in which turbulent flow appears or to the observable effects it produces. Perhaps the best statement of this type is that of G. I. Taylor[1]*, who writes: " Turbulence is an irregular motion which in general makes its appearance in fluids, gaseous or liquid, when they flow past solid surfaces or even when neighbouring streams of the same fluid flow past or over one another ". A great deal of progress has been made in the elucidation of the problem under laboratory conditions (by means of wind-tunnel experiments, etc.) but in the atmosphere, with its variable boundary surface and changing temperature conditions, there are many further complications, and as yet we are far from solving it.

The aim of this article is to emphasise and discuss a few recent qualitative ideas in the study of atmospheric turbulence as well as to give a brief account of at least one special theory. I have made free use of ideas and forms of words to be found in the general literature of the subject, with particular reference to a paper by C. H. B. Priestley and W. C. Swinbank[2], and have embedded them, so to speak, in a critical commentary of my own. The treatment is necessarily sketchy, but it is hoped that it will help to clarify some of the difficulties to be overcome before the problem is understood, and to suggest some useful ideas to the practising meteorologist.

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* The index figures refer to the references on p. 82.

Eddy diffusion, mixing and transport.—The earlier theories of turbulence were based on a direct analogy with the kinetic theory of gases. The irregularities in turbulent motion were compared to the molecular agitation which gives rise to such physical properties of the fluid as pressure, temperature and viscosity. Just as gaseous diffusion was explained by the motion of the constituent molecules, the changes in the average distribution of certain atmospheric properties were thought of, and still are, as resulting from the movement of elementary volumes or particles of air, small by everyday standards but large by comparison to the mean free path of the molecules, forming part of an eddy. This process was called, appropriately enough, eddy diffusion. No definite meaning could be ascribed to the word " eddy " in all cases, but in as far as it conveyed the idea of movement in accordance with a set pattern it corresponded roughly with observations of certain types of fluid motion.

Eddies are the visible agents in the spread of transferable properties in a fluid medium. They are of all sizes, the smaller ones often forming part of and moving with the larger, and are constantly being formed and dissipated again. Although the details of the motion are conveniently ignored, the concept of eddy diffusion is a necessary preliminary to our understanding of the mixing process. Ultimately, mixing is a comparatively slow process of molecular diffusion, but it can be enormously facilitated by the bodily movement of lumps of fluid constituting eddies, and by their gradual mechanical disruption. An eddy, considered as a stationary " whorl " only losing its excess temperature, say, by molecular diffusion through its boundaries, would not be nearly so good a transporter of heat as one that moved as a whole, and at the same time disintegrated, thereby presenting a much greater surface area to the colder environment.

But, however complete the picture, we are still faced with the difficulty of describing in mathematical terms the evolution and decay of an eddy; and, up to the present, no theory of turbulence pretends to be a theory of the diffusion of or by eddies as such. In order to formulate any sort of theory at all, simplifying assumptions must be made. Some of them are at variance with the known physical properties of fluids, while others are occasioned by lack of observational knowledge. Before proceeding it is necessary to analyse the idea of diffusion more completely.

The two basic concepts are transport and mixing. The motion of an elementary volume of fluid can be considered abstractly in itself, but in practice the simultaneous transport of certain properties cannot be dissociated from molecular mixing, and exchanges of property across the boundaries of the particle are always going on. Mixing, in this sense, is a continual process, and although this has been clearly recognised there is only one theory which takes it into account, namely that of O. G. Sutton[3] who developed Taylor's theory of diffusion by continuous movements[1] and applied it to the atmosphere. Even in Taylor's theory molecular mixing has no effect on the diffusive power of turbulent motion; it is merely concerned with the mixing due to the relative motion of individual fluid particles whose properties remain invariant indefinitely. The, so called, mixing-length theory given subsequently also approached the problem in this manner, and presents an idealised picture of the motion under discussion.

The real atmosphere.—In a turbulent atmosphere the wind velocity is naturally subject to continual variations, both large and small, which may readily be seen on any anemograph trace. A large proportion of the fluctuations near the ground seem to have a period of about one second, though almost any period may occur from a fraction of a second to many days. One would expect other properties to show similar irregularities and a glance at a typical autographic trace confirms this. As yet, except for wind velocity, instruments of sufficient sensitivity have not been developed to follow the finer details of these microvariations, but such variations undoubtedly occur.

We cannot hope to describe the irregularities of the turbulent state in detail, and, after all, the average distribution of various properties in space is of greater practical importance. Yet we cannot afford to ignore reality altogether, and the principal defect of earlier theories was the over-simplified notions of the atmosphere that they were based on. Priestley and Swinbank have remedied this to a certain extent, and the following is a generalised treatment of their paper.

Mathematical theory.—In the absence of any adequate concept of mixing as a continual process one is forced to accept the limitation of considering moving elements of a fluid as particles which preserve their identity in moving from one point to another. If θ stands for the amount of a transferable property of the atmosphere per unit mass, we may denote its mean value by $\bar{\theta}$, so that $\theta = \bar{\theta} + \theta'$. For velocity, θ' is simply the " eddy velocity " of Osborne Reynolds, and this convention can be extended to other properties. Thus one can speak of the " eddy temperature ", for example, but for reasons given later this is not completely satisfactory, and, following Priestley and Swinbank, the expressions " temperature anomaly ", " moisture anomaly ", etc., will be used for the departure of temperature, moisture content, etc., from their mean values. The arithmetic mean of the property in question is normally taken either with regard to time at a fixed point, or over a given area at a particular instant of time.

The flux across a small element of surface area δS is equal to $\rho w \theta \delta S$ where w is the wind velocity normal to δS, and ρ is the density of air, so that the average flux per unit area per unit time is $\overline{\rho w \theta}$, the mean being taken over the surface at a fixed time. If this surface is an isobaric surface then $\overline{\rho w} = 0$, since there can be no net transport across it, and the flux may be written $\overline{\rho w \theta'}$. In the atmosphere isobaric surfaces are for all practical purposes plane horizontal surfaces, and we may therefore represent the vertical flux by the equation $F = \overline{\rho w' \theta'}$, where w' is now the vertical component of the eddy velocity, assuming there is no mean vertical velocity (i.e. $\bar{w} = 0$). Horizontal mean gradients are normally negligible by comparison with vertical gradients, so that $\bar{\theta}$ and F may be taken as functions of z, the height, and t, the time, only, and written $\theta\ (z, t)$ and $F\ (z, t)$ where necessary.

Considering a small volume between two isobaric surfaces of unit cross-section and thickness δz, the flux across the lower one is F and across the upper $F + (\partial F/\partial z)\delta z$ to the first order, and the mean accumulation (i.e. inflow minus outflow) in the elementary volume is $-(\partial F/\partial z)\delta z$ per unit area, per unit time. The amount of the property between the two planes is $\rho\theta\delta z$ per unit area, so that $\overline{\{\partial(\rho\theta)/\partial t\}}\delta z$ is the mean rate of change per unit area per unit time. Therefore

$$\overline{\frac{\partial}{\partial t}(\rho\theta)\delta z} = \frac{\partial}{\partial t}(\overline{\rho\theta})\delta z = -\frac{\partial F}{\partial z}\delta z,$$

and the fundamental equation becomes

$$\frac{\partial}{\partial t}\overline{(\rho\theta)} = -\frac{\partial}{\partial z}\overline{(\rho w'\theta')}.$$

Now the atmosphere may be assumed to be homogeneous and incompressible over a limited depth without appreciable error, i.e. ρ is constant, hence

$$\frac{\partial\bar{\theta}}{\partial t} = -\frac{\partial}{\partial z}\overline{(w'\theta')} \quad \text{.. (1)}$$

Since $\overline{w'\theta'}$ is not directly measurable as yet, we must express it more conveniently before a solution is possible. An elementary particle of fluid may be considered to have originated at a vertical distance l below the datum level, where the mean value of the property is $\bar{\theta}(z-l, t)$, which is approximately equal to $\bar{\theta} - l\partial\bar{\theta}/\partial z$, l being positive. The actual value of the property at this level is $\bar{\theta} - l\partial\bar{\theta}/\partial z + \theta''$ where θ'' is the anomaly there, and since it is conserved during the passage of the particle to the datum surface, $\theta' = -l\partial\bar{\theta}/\partial z + \theta''$. This equation is only valid if l is small, or if the higher derivatives of $\bar{\theta}$ above the first are small, and provided the time of travel is so short that no significant change in the mean property takes place in the meantime. Substituting for θ' in the equation of flux, we get

$$F = -\overline{w'l}\frac{\partial\bar{\theta}}{\partial z} + \overline{w'\theta''} \quad \text{.. (2)}$$

and equation (1) becomes

$$\frac{\partial\bar{\theta}}{\partial t} = \frac{\partial}{\partial z}\left(\overline{w'l}\frac{\partial\bar{\theta}}{\partial z} - \overline{w'\theta''}\right) \quad \text{.. (3)}$$

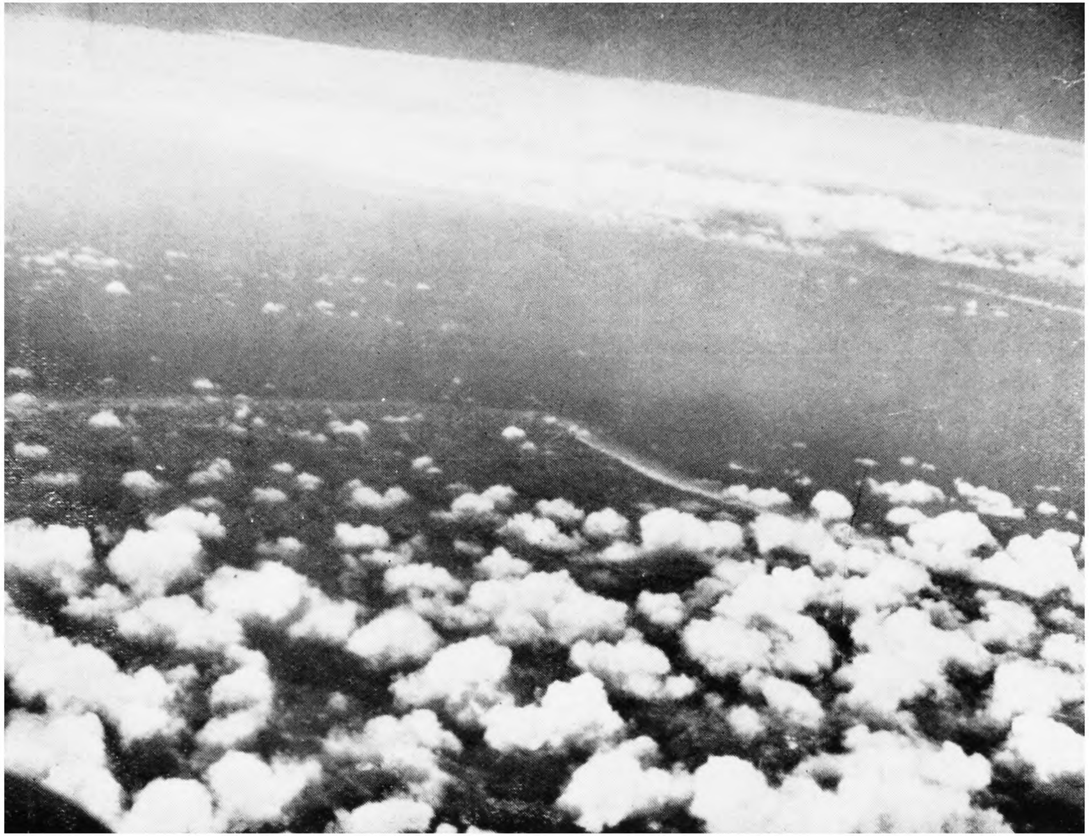
$$= \frac{\partial}{\partial z}\left(K_\theta\frac{\partial\bar{\theta}}{\partial z}\right) \quad \text{. (4)}$$

where

$$K_\theta = \overline{w'l} - \frac{\overline{\boldsymbol{w'l}}}{\frac{\partial\bar{\theta}}{\partial z}} \quad \text{.. (5)}$$

K_θ is known as the coefficient of eddy diffusivity for the property under consideration. Equations (4) and (5) do not apply for $\partial\bar{\theta}/\partial z = 0$, and when this is so we shall have to revert to equation (3). It is interesting to note that according to this equation there can still be a flux of the property even when there is no mean gradient, although in this case molecular diffusion would soon smooth out the anomalies making both $\overline{w'\theta''}$ and F tend to zero simultaneously.

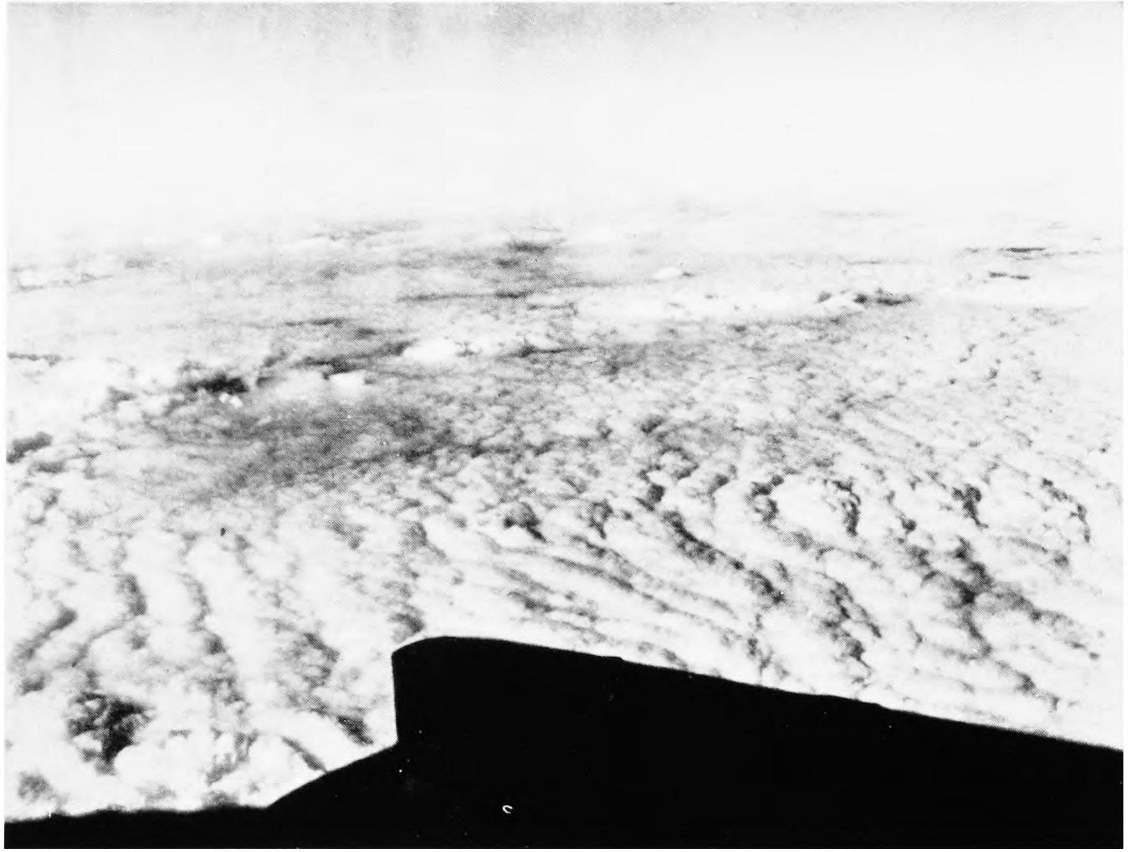
In the old classical theory the level of origin of an elementary particle was conveniently chosen as that at which the property had a value equal to the mean value of its environment so that $\theta'' = 0$, and K_θ reduces to the more familiar form $\overline{w'l}$. But there is no reason to suppose that the property associated



SMALL CUMULUS CLOUD OVER ENGLAND AND FRANCE LEAVING THE ENGLISH CHANNEL CLEAR

Photograph taken from 14,000 ft. at 1058, June 27, 1944.

To face p. 81]



CUMULUS HEADS PROTRUDING THROUGH ALTOCUMULUS SHEET

Photograph taken over Paris from 29,000 ft. at 1545. October 2, 1943.

with an element of fluid ever had a value equal to the mean value of its environment, or if it had, that l is a small distance. Obviously the particle could have had a very varied and lengthy career from the time it last had this property to when it reached the datum level (which it might have traversed in opposite directions more than once) and the lifetime of a particular volume may not be short by comparison with the time scale of any net average change of the mean property at any level. Also, a long time of travel implies less likelihood of an element preserving its properties unchanged; the only thing that makes the theory anything like tenable is shortness of travel both with respect to time and vertical distance. As Priestley and Swinbank pointed out, it was more logical to regard the level of origin as that level at which the eddy was last at rest in the vertical before penetrating the datum surface.

In defining such parameters as $\overline{w'l}$ and $\overline{w'\theta''}$ no reference has been made to the size of the area over which the mean is taken. However there are necessary limitations of size, since the area must not be so small as to exclude the passage of a representative number of eddies, i.e. it must be large compared with what one might call the " effective " eddy diameter, and it must not be large enough to include significant horizontal variations in the mean property. It is one of the conditions of formulation that horizontal gradients are non-existent, and when they do occur sideways eddy diffusion makes its contribution to the flux. We have, in effect, reduced atmospheric motion to two dimensions, one of space and one of time, and for ordinary purposes this suffices. The above equations apply to any fluid medium for which the assumptions hold—the oceans as well as the atmosphere—and in practice either " space " means or means with respect to time at a fixed point, which are the ones normally available, may be used.

Mixing and transport lengths.—The length l introduced in the previous section is often called a " mixing length ", although this is evidently a misnomer. Up to now no reference has been made to mixing at all, in fact, it is explicitly assumed that the properties of a fluid are carried without mixing in the sense already referred to; l is more accurately a " transport length ", and this name will be retained in what follows except where convenience of reference to current usage prohibits it. Strictly speaking a mixing length should be the length of the path, traversed by an elementary volume of fluid from the point of origin to where it has completely mixed with its environment. This length, as such, remains unchanged whether we conceive of the process as one in which the element retains its identity until the end of its path and then mixes " instantaneously " with its environment, which is the sort of process envisaged in transport-length theories, or as a continual process of mixing until it is indistinguishable from its surroundings.

However, there are several difficulties in this definition. First, what is meant by the level of origin ? Probably the best answer is that given by Priestley and Swinbank, *viz.* that it is the level at which the particle was last at rest in the vertical. Secondly, when is complete mixing effected ? The best answer seems to be, when the property of an element first reaches a value equal to the average value (horizontally) of its environment at that instant. If the motion were suddenly arrested at this end point there would be no ultimate change in the value of the property due to further (molecular) mixing. It will be noticed that both at the level of origin ($w' = 0$) and at the end point ($\theta' = 0$),

$\rho w' \theta'$ is zero, and the moving element contributes nothing to the total flux at the two levels. The scheme corresponds roughly to the life-cycle of an eddy considered as an agent of diffusion, since initially an element would begin to move under the influence of a newly formed eddy, or if it were already moving horizontally in an eddy it would only become effective in the vertical transfer when it does start to move vertically, and the final extinction of the anomaly would often mark the decay of an eddy. But this interpretation of mixing length is inadequate inasmuch as it does not describe every phase in the life of a moving particle. Even after it has acquired the mean property of its environment a particle can still continue to rise and be subject to further mixing before either coming to rest again in the vertical or acquiring a fresh mean value at another level. Thus it is evidently possible to define several types of mixing length from this point of view alone.

In the transport-length theory given above we are only concerned with the level of origin of an elementary volume of fluid, not its ultimate history, and the chief difference between the older classical theory and that of Priestley and Swinbank is in the definition of this level. In the former a particle is concerned as originating with the mean property of its environment, and in the latter it starts from rest in the vertical having properties which differ from the properties at its level. Since the elementary particles move with relatively large masses of air in an individual eddy it is obvious that, during its passage to the level of reference, molecular mixing tends to destroy the existing anomalies. Similarly for the bigger eddies, a large mass may be considered to have come from a common level, and the sideways mixing due to diffusion by smaller eddies, which has been ignored in the theory, helps to smooth out the large-scale initial differences during transit. In other words, an elementary volume may be considered as effectively having started at a level with more or less uniform properties horizontally, and it is to be expected that the truth lies somewhere between the two theories. But the differences between the mean values of the properties associated with the largest and most effective eddies still have to be reckoned with, and, in spite of the general loss or gain of property across the boundaries, must be allowed for in the formulations. The second term in the flux equation is undoubtedly real, and represents a new approach to the problem of atmosphere turbulence. A fuller discussion of its significance and advantages will be given in the next article.

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METEOROLOGICAL OFFICE DISCUSSIONS

The third Monday evening discussion of the present session was held in the lecture theatre of the Science Museum on February 23. Mr. O. M. Ashford opened the discussion, which dealt with an unpublished paper by Dr. R. Schulze on the requirements and classification of radio-sondes.

Mr. Ashford explained that the paper was prepared about the end of the war as an introduction to a series of papers by officers of the German Marine Observatory, Greifswald, on the application of radio-sondes to meteorology and ballistics. The first part of the paper dealt with the range and accuracy requirements of radio-sondes for various applications. Two values were given under each heading, an " acceptable " value and a " desirable " value. For synoptic work the desirable accuracy was stated as ± 0·4°C. in temperature, ± 3 per cent. in relative humidity and the equivalent of ± 100 m. height in pressure (i.e. ± 3 mb. at ground level to ± 0·2 mb. at 20 Km.). The difficulty of meeting these requirements was emphasised by pointing out that the German standard for a precision electrical instrument was only ± 0·5 per cent. of the range, which would correspond to ± 0·5°C. and ± 5 mb. in temperature and pressure for a radio-sonde.

The remainder of the paper described a system of classification of all known radio-sondes into temperature-sondes (giving pressure, temperature and humidity), wind-sondes (giving wind) and weather-sondes (pressure, temperature, humidity and wind), with further subdivisions into active- and passive-sondes, and mechanical- and electrical-sondes.

In discussing the paper Mr. Ashford said that there was a need for a clear statement of accuracy requirements by upper air analysts. Careful distinction should be made between probable errors and 90 per cent. errors, and between systematic and random errors. From the instrument designers' point of view there were numerous interesting possibilities of improving the accuracy of radio-sondes, such as the use of a hypsometer for measuring pressure, but the vital question of cost had always to be borne in mind. The possibility of applying corrections for instrument lag and radiation errors ought to be investigated.

In the discussion which followed, the Director mentioned the work on a sonic velocimeter being carried out at Oxford, and pointed out that a limit to the desirable accuracy was set by the variability or patchiness of the atmosphere. Dr. Harrison mentioned the attempts that were being made to assess the accuracy of radar methods of measuring upper winds. Dr. Scrase remarked that the question of desirable accuracy had been raised at the I.M.O. Conference at Washington but no definite conclusions had been reached. Prof. Sheppard preferred the use of 90 per cent. errors rather than probable errors, and suggested that progress might be made by the introduction of different types of instruments, e.g. a radio-sonde which gave out a signal when it reached standard pressure levels, the height being measured by radar. Mr. Gloyne thought that a certain amount of instrument lag was desirable, as it smoothed out the small-scale variations. Mr. Oddie, however, thought it better to record the fine structure and apply the smoothing subsequently as desired.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society, held at 49, Cromwell Road, on February 18, with Prof. G. M. B. Dobson, President, in the Chair, the following papers were read:—

R. C. Sutcliffe—A contribution to the problem of development.

This paper grew out of an earlier one by the same author (1939) in which it was argued that development in the atmosphere consists of a vertical distribution of divergence and convergence such that the integrated divergence, defining the surface pressure tendency, is a small residual of opposing contributions at different levels. It was then inferred that development could be diagnosed by finding the difference between the divergence at the surface and some upper level. Since geostrophic motion is non-divergent it is to be expected that a study of the field of acceleration difference between two convenient levels (associated with departures from geostrophic flow) would indicate the nature of the development. In the present paper Dr. Sutcliffe developed the same general argument in terms of the change of vorticity, which is closely connected with the curl of acceleration.

In passing, he defined " subsidence " and " ascent " as states in which dp/dt is positive or negative respectively, and pointed out that either may extend through the whole troposphere into the stratosphere even though the divergence changes sign at some intermediate level. He also remarked that in many cases a study of the dynamics of the surface motion alone is insufficient to indicate the nature of significant developments. The appearance of abnormal weather in complex thermal structures may be expected without indications from surface observations (including pressure tendencies).

His fundamental equation is

$$l\,(\mathrm{div}_p\mathbf{V} - \mathrm{div}_p\mathbf{V}_o) = -V'\frac{\partial}{\partial s}(l + \zeta + \zeta_o)$$

in which the left-hand side denotes the relative (isobaric) divergence between two pressure levels (> 0 for cyclonic and < 0 for anticyclonic development), V' is the relative wind (or shear) between the same two levels, ζ and ζ_o are the respective vorticities, l is the Coriolis parameter $2\omega \sin \phi$, and $\partial/\partial s$ denotes differentiation in the direction of shear. It is obvious from the equation that there can be no development without shear. The formula is derived from the normal tendency equation by means of the intermediate equation

$$l\,(\mathrm{div}_p\mathbf{V} - \mathrm{div}_p\mathbf{V}_o) = -\mathbf{V}.\,\nabla_p(\zeta + l) + \mathbf{V}\cdot\nabla_p(\zeta_c + l) - \frac{1}{l}\left(\frac{\partial}{\partial t}\right)_p \nabla_p{}^2 h',$$

where h' is the " thickness " between the isobaric surfaces. Assuming that the motion is quasigeostrophic, i.e. the wind nearly balances the pressure gradient, the approximate equation

$$\zeta = \frac{1}{l}\,\nabla_p{}^2 h = \frac{1}{l}\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)_p h$$

is deduced, h being the absolute height of the pressure level, the suffix, p, implying differentiation at constant pressure. These two links lead directly to the first equation, assuming, among other things, that the direction of wind shear is invariant with height over the layer, that there is no vertical motion, and that the effect of adiabatic and direct heating and cooling processes on the resulting thermal field, may be ignored by comparison with advection. The author recognised that the latter two effects were definitely significant in certain situations.

In applying these ideas to forecasting it is formally possible to determine the important relative divergence factor for the thickness layers between the 1000-mb., 750-mb., 500-mb., and 300-mb. surfaces, so as to get some indication of the development taking place. Subject to the assumptions made, the problem reduces to that of determining the quantity $(\partial^2/\partial x^2+\partial^2/\partial y^2)h$ on the various charts, representing the results by isopleths and then estimating the value of the gradient along the direction of the shear vector. Dr. Sutcliffe stated that such a procedure had been tested quantitively over a considerable period with some promise, and he hoped next to undertake a series of synoptic studies. The method did permit of an estimate of the development between existing and forecast charts and did allow of a further rough extrapolation, whereas the old method based on observed tendencies did not. He concluded by saying that his ideas did not represent the complete story, but since the arguments and deductions were susceptible both to physical interpretation and practical test they might be of value. With experience, a forecaster should be able to arrive at something better than almost pure empiricism.

C. H. B. Priestley—Dynamical control of atmospheric pressure.

This paper, in the absence of the author, was read by Prof. P. A. Sheppard. It is mainly concerned with the movement of pressure systems without distortion and development, which amounts to finding the surface pressure tendencies throughout the field of flow under these conditions, and seeks, like the first, to explain why the realised pressure tendency invariably emerges as a small residual of its much larger primary components. His thesis is that the field of flow determines the pressure change, but itself depends dynamically on the instanteous pressure-tendency field. It is this mutual interaction between the two fields which constitutes the brake or control on the mutability of the pressure field.

The author shows that purely geostrophic motion implies very large tendencies for north-south flow, which are not compensated by vertical velocities of the order found in nature, and he is therefore led to consider the changes associated with a geostrophic flow. He ignores those due to acceleration along the path (unlike Sutcliffe), vertical velocity and surface friction and merely discusses the effect of deviations due to curvature of the path. Thus the true wind is replaced by a suitably defined gradient wind, and the tendency equation is expanded in terms of the divergence of gradient momentum. An appendix to the paper gives a new interpretation to the gradient wind which is adopted throughout.

A number of applications are made with the object of explaining the broad features of the translation of idealised pressure systems, and many practical forecasting rules are deduced, some of them already well established. In addition, an indication is given as to how the principle of control may be used to clarify some problems of development, the extent of which depends on the asymmetry of the pressure system about its meridional axes. Finally, the author acknowledges that deviations from the gradient wind may be large at times and states that he hopes to make a closer study of them later.

J. S. Sawyer—Notes on the theory of tropical cyclones.

Mr. Sawyer started by describing the conventional picture of the development of tropical storms, and said that the chief difficulty is to explain the eviction of air from the upper levels of the cyclone after the initial rise of pressure had been equalised and the circulation had become cyclonic at all levels. In his paper he considers the condition under which continued outward motion is possible in a circular vortex, and arrives at the following criteria for the formation of a revolving storm, viz :—

(*a*) A lapse rate which will give rise to vertical instability and the development of cumulonimbus cloud.

(*b*) A distribution of circulation at some level aloft such that anticyclonic circulation increases outward at a rate exceeding a certain value.

(*c*) A distribution in the vertical of horizontal rotation such that the cyclonic distribution decreases with height.

The surface vortex is characterised by the relation vr=constant (r being the distance from the centre and v the tangential velocity), which obviously must break down towards the centre. The author suggests that very large values of v are prevented by the turbulence due to horizontal wind shear, and it is this effect which is responsible for the calm " eye " of the storm. The relation between tropical cyclones and fronts is briefly discussed in conclusion.

In the ensuing discussion all three papers were taken together ; Prof. Brunt, Prof. Sheppard, Mr. Douglas, Mr. Durst and Mr. Eady were the principal speakers. Attention was drawn to the large number of approximations and assumptions made in order to treat atmospheric flow mathematically, although this was as much a source of congratulation for the brilliant way in which it had been done, as an object of criticism. Prof. Brunt did not consider the use of geostrophic winds could give accurate results, while Mr. Douglas could see no improvement, from a practical forecasting point of view, without an understanding of fundamental atmospheric processes, although he considered the insistence of Dr. Sutcliffe on a study of the changes in the thermal field—thickness-line technique, and vector shear—represented a real advance. He agreed that much of the movement of pressure systems was in the nature of development. Mr. Durst shared the general scepticism of the qualitative results to be expected from the papers, and thought that the application of electronic devices to numerical solution of the equations of motion may ultimately be necessary. Perhaps the most illuminating remarks of the evening came from a mathematician, Dr. McVittie of King's College, London, who had recently examined the equations of motion used by meteorologists. He pointed out that the earth was round, not flat, that air was a gas, not a liquid, and suggested that a more realistic scheme of co-ordinates should be adopted and the fact of atmospheric compressibility taken into account.

In replying, Dr. Sutcliffe thought that such quantities as divergence and vorticity, which were first derivatives, were not appreciably affected by using Cartesian co-ordinates. Mr. Sawyer, while agreeing with Dr. McVittie, said that simplifications were necessary to reduce the complexity of dynamical problems. His own treatment was only intended to give an indication of the way in which a tropical cyclone might evolve.

THE ROYAL SOCIETY

The paper, " Correlation between climate, forest composition, prehistoric archaeology, and peat stratigraphy in the Somerset Levels " by A. R. Clapham and H. Godwin, F.R.S., read before the Royal Society on February 19, gave a striking example of the possibility of linking together botanical and archaeological evidence to reveal changes in climate.

The area considered in this paper is that between the Mendip and Polden Hills in central Somerset. The area is a plain called the Somerset Levels floored by clay which filled up much deeper valleys during a transgression of the sea in late glacial times. On this clay there grew extensive peat bogs which are now being worked for fuel.

The authors cut sections in the peat and found two layers of varieties, *Cladium-Hypnum*, *Aquatic Sphagna* and *Scheuchzeria*, known to grow under flooded conditions with the variety, *Sphagnum Calluna-Eriophorum*, growing under drier conditions, below and between them. At the lower level in question there occur wooden trackways buried in the peat running between areas of high ground. These trackways are made of substantial logs supported by long stakes driven into the peat below and held by longitudinal stringers. The cut ends of the logs bear marks of the size and shape appropriate to the axes made in late Bronze Age times. Further evidence for the culture in which the tracks were constructed was provided by a bronze spearhead of the same period found by a peat digger at the same horizon. This places the swamping at about 500 B.C. This is the time at which the cold wet period, known as the sub-Atlantic commenced.* The trackways themselves are, the authors pointed out, confirmatory evidence of swamping since they are not needed for safe crossing of normal peat and must have involved a great deal of effort.

The higher layer of the variety of peat growing under flood conditions was dated archaeologically by a Romano-British interment just above it and is considered by the authors to have formed about A.D. 250.

Further evidence in support of their arguments was provided by analysis of the pollen grains found in the peat. This analysis showed a great decrease at the flooding levels in the proportion of the pollen of cereals and of weeds which grow on cultivated ground.

LETTER TO THE EDITOR

Development of cumulus over fires

The letter in your issue of June 1947, p. 139, describing the growth of cumulus over a tar fire seems to suggest a rarity for what is a very common process, in the tropics especially. The finest clouds of this type are over forest fires ; a beautiful picture of one was given in this magazine for April 1939. The rising columns of heat and smoke over the countless bush fires of tropical grass lands in the dry season often develop plumes of cumulus, the bluish haze of the smoke changing to the dazzling white of the cloud in a way that is as beautiful as it is instructive. A much smaller conflagration may suffice ; in the tiny island of Agaléga in the tropical Indian Ocean (10° 26′ S., 56° 40′ E.) I have seen a large patch of cumulus growing at the top (altitude some 3,000-4,000 ft.) of the column of smoke from a small native bonfire of garden refuse ; this naturally tends to occur about midday on a sunny day in the rainy season, when the sluggish air is excessively moist and hot (physiologically), and the lapse rate is very steep.

W. G. KENDREW

Oxford, March 3, 1948.

NEWS IN BRIEF

Mr. Gordon Manley M.A., M.Sc. has been appointed to the University Chair of Geography at Bedford College, University of London.

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* BROOKS, C. E. P.; Unsolved problems of climatic change. *Met. Mag., London*, **76**, 1948, p. 128.

NOTES AND NEWS

Admiral Fitzroy's clock

During the war the Meteorological Office received an interesting memento of its first Director, Admiral Fitzroy (1855-1865), in the form of a clock which was presented to Admiral Fitzroy by the Minister of Marine and Colonies of France.

On his appointment as Director, one of Admiral Fitzroy's first steps was to organise a system of storm warnings for ships. In doing this he was taking advantage of the recently introduced electric telegraph, prior to which such a system of warnings was, of course, impossible. Admiral Fitzroy decided to share the advantage of his warning system with the French, and he made arrangements for the warnings to be telegraphed to Paris, whence they were distributed for the benefit of the French Navy, merchant navy and fishing fleets. It was in recognition of the services thus rendered that the French Government presented Admiral Fitzroy with the clock which forms the subject of this note.

The clock is a beautiful specimen of the travelling clocks of that period, and its general appearance can be seen from Fig. 1. The movement is contained in a gilt case standing 7½ in. high, with bevelled glass panels forming the sides, and bearing richly chased steel figures on the corner columns. In addition to the ordinary dial, the clock has subsidiary dials showing the day of the week, day of the month and month of the year. It also has an alarm and repeater mechanism which strikes the last hour and quarter on pressing a stud on the top of the clock case.

The glass plate which forms the top of the case is engraved with the following inscription :—

" Offerte par le Ministre de la Marine et des Colonies au Vice-Admiral Robert Fitzroy, Esq., Chief of the meteorological department of the Board of Trade, pour services rendus à la Marine Impériale, 1864."

This beautiful and historic clock was bequeathed to the Meteorological Office by a daughter of the Admiral, Miss Laura Fitzroy, who died in 1943. It forms a treasured memento of a great man, who was not only the first Director of the Meteorological Office, but whose energy was in large measure responsible for its formation.

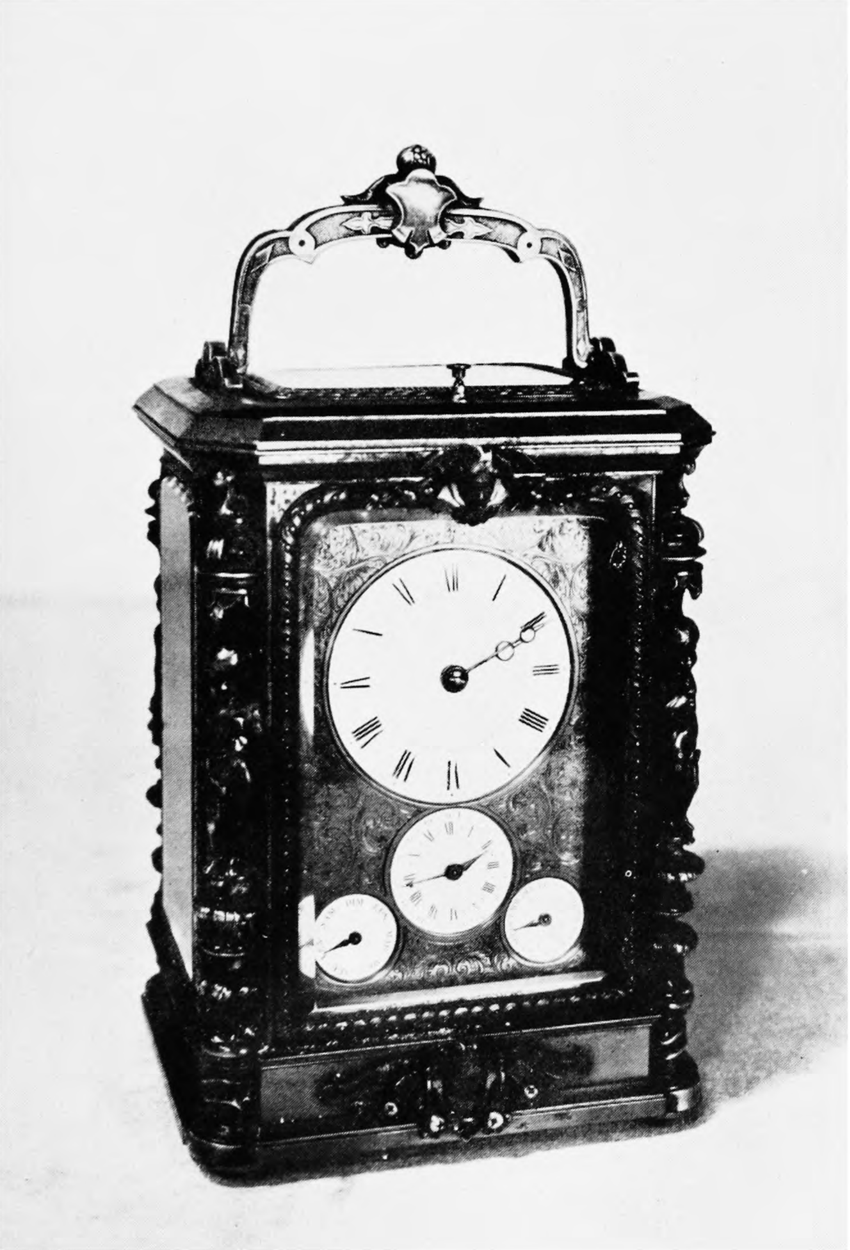
N.K.J.

New York snowstorm, December 26, 1947

The effects of the great snowstorm in New York on December 26, 1947, will be familiar from newspapers and newsreels.

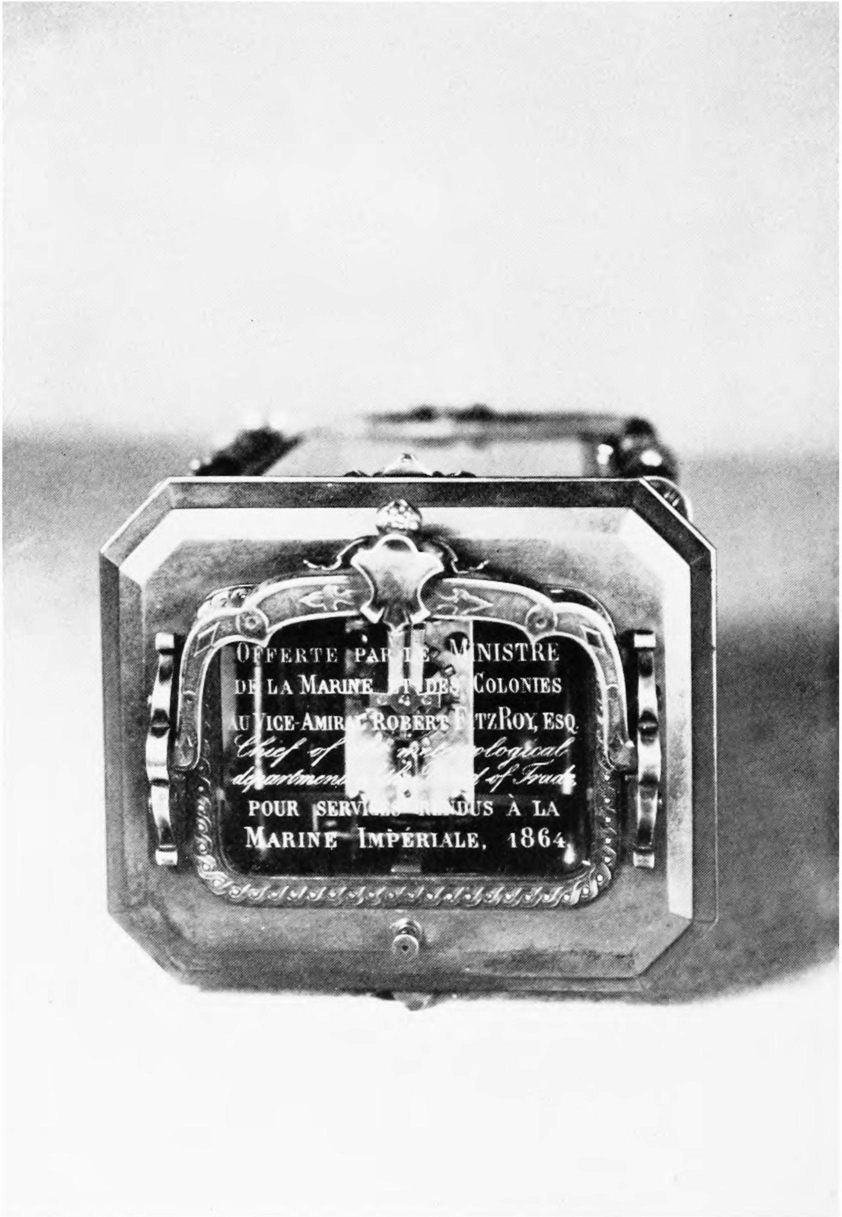
We welcome the opportunity of giving, by courtesy of the U.S. Weather Bureau, an account of the meteorological conditions which gave rise to the snowfall. The Weather Bureau selects each month an interesting or unusual situation for detailed analysis, and publishes the results with charts on the back of its *Daily Weather Maps*. Nearly all the information and all the maps which follow are taken from analysed Series No. 36 published on the back of the *Daily Weather Maps* of February 9 and 10.

The total fall of snow in New York city during the storm was 25·8 in. and at places in the surrounding country it reached 30 in. Such a total amount is not extremely rare in a single storm, though fortunately it does not often fall on a great city, but the rate of fall, 1·8 in./hr. from 5 a.m. to 7 p.m. was quite exceptional.



ADMIRAL FITZROY'S CLOCK

To face p. 89]


OFFERTE PAR LE MINISTRE
DE LA MARINE ET DES COLONIES
AU VICE-AMIRAL ROBERT FITZROY, ESQ.
Chief of the meteorological
department Board of Trade
POUR SERVICES RENDUS À LA
MARINE IMPÉRIALE. 1864.

ADMIRAL FITZROY'S CLOCK, SHOWING INSCRIPTION

Fig. 1 shows the synoptic situation at 7.30 p.m. (eastern standard time) on December 25. The depression centred off Cape Hatteras had formed over Alabama on the 23rd and moved north-eastwards to the Atlantic. A nearly stationary front extended north from the depression, and on this front there formed a small " wave " which soon deepened and was a prime cause of the storm. Another depression was centred over the Great Lakes.

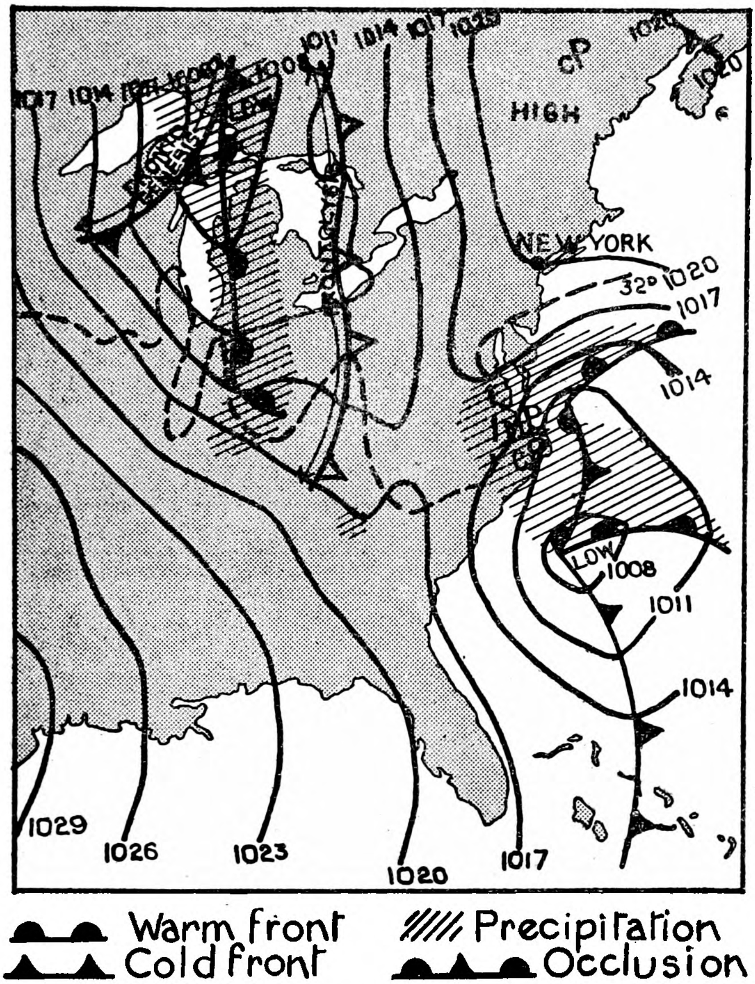

1017
1014
1011
1014
1017
1020
cP
HIGH
1020
NEW YORK
32°
1020
1017
1014
LOW
1008
1011
1014
LOW
1029
1026
1023
1020
1017
Warm front
Cold front
Precipitation
Occlusion

FIG. 1—SYNOPTIC CHART 7.30 P.M. E.S.T., DECEMBER 25, 1947

At 7.30 a.m. December 26 (Fig. 2), the wave, with a central pressure only some 5 mb. less than on the previous evening was centred some 150 miles south-east of New York. The original depression off Cape Hatteras had by this time moved away eastwards. The Great Lakes depression had also moved eastwards. Snow began to fall in New York in the early hours of the morning and at the time of the chart it was snowing heavily. The 500-mb. contour chart, for 10.30 a.m. December 25, Fig. 3, shows that at that level, about 18,000 ft., the dominant feature was a depression over the Great Lakes due to a combination of rather low surface pressure and very cold air. At 500 mb. the wind over the Atlantic coast was southerly about 50–70 m.p.h. The Weather Bureau analyser considered this strong southerly wind aloft to have caused the Atlantic depression to move north-north-east, so bringing the snow to New York, instead of, as would normally be expected, moving to north-east.

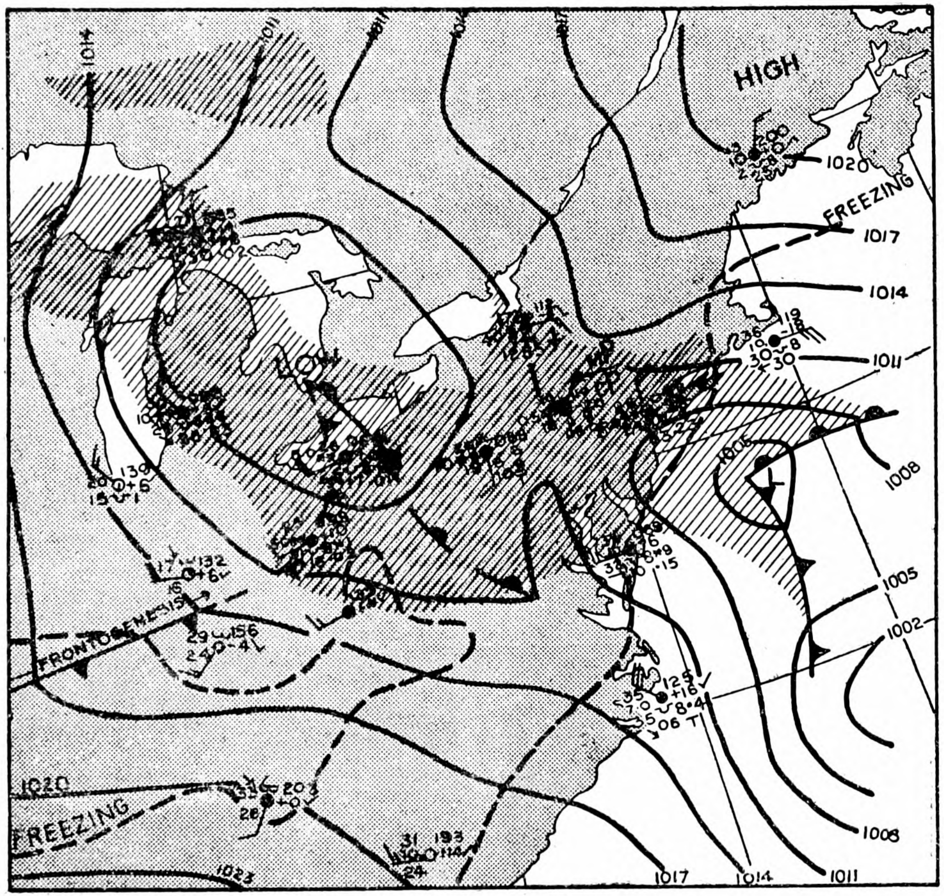

HIGH
LOW
FREEZING
FRONTOGENESIS
1020
1017
1014
1011
1008
1005
1002
1008
1011
1014
1017
1023
1020
1014
1011

FIG. 2—SYNOPTIC CHART, 7.30 A.M., E.S.T., DECEMBER 26, 1947
For explanation see Fig. 1.

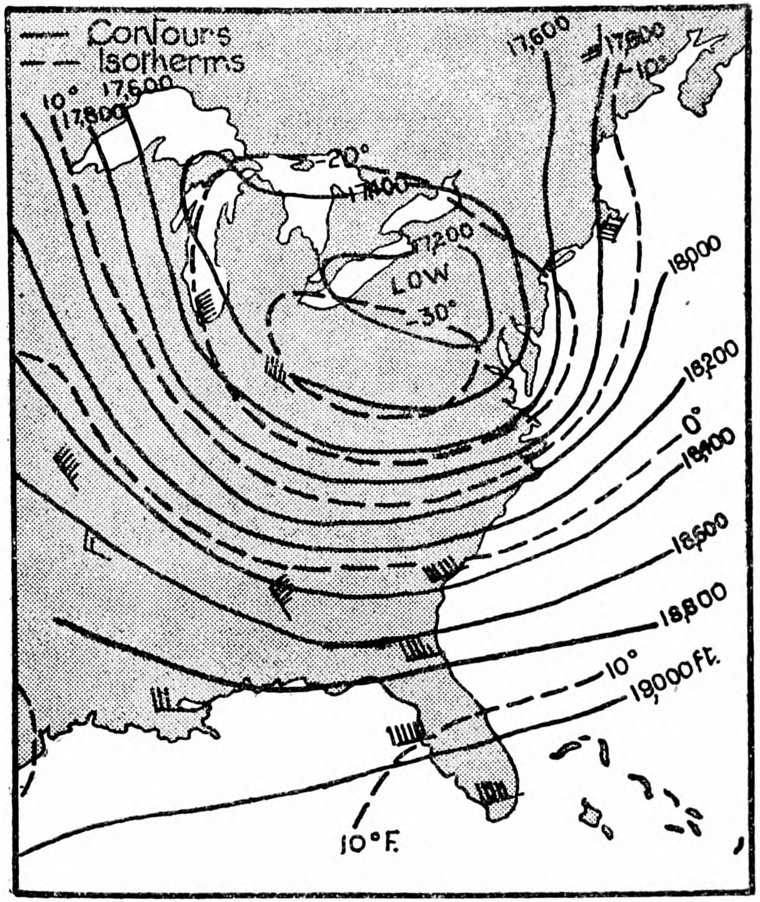

Contours
Isotherms
17,600
17,800
10°
17,600
17,800
10°
-20°
17,400
17,200
LOW
-30°
18,000
18,200
0°
18,400
18,600
18,800
10°
19,000 Ft.
10°F.

FIG. 3—500-MB. CONSTANT-PRESSURE CHART, 10.30 A.M., E.S.T., DECEMBER 26, 1947

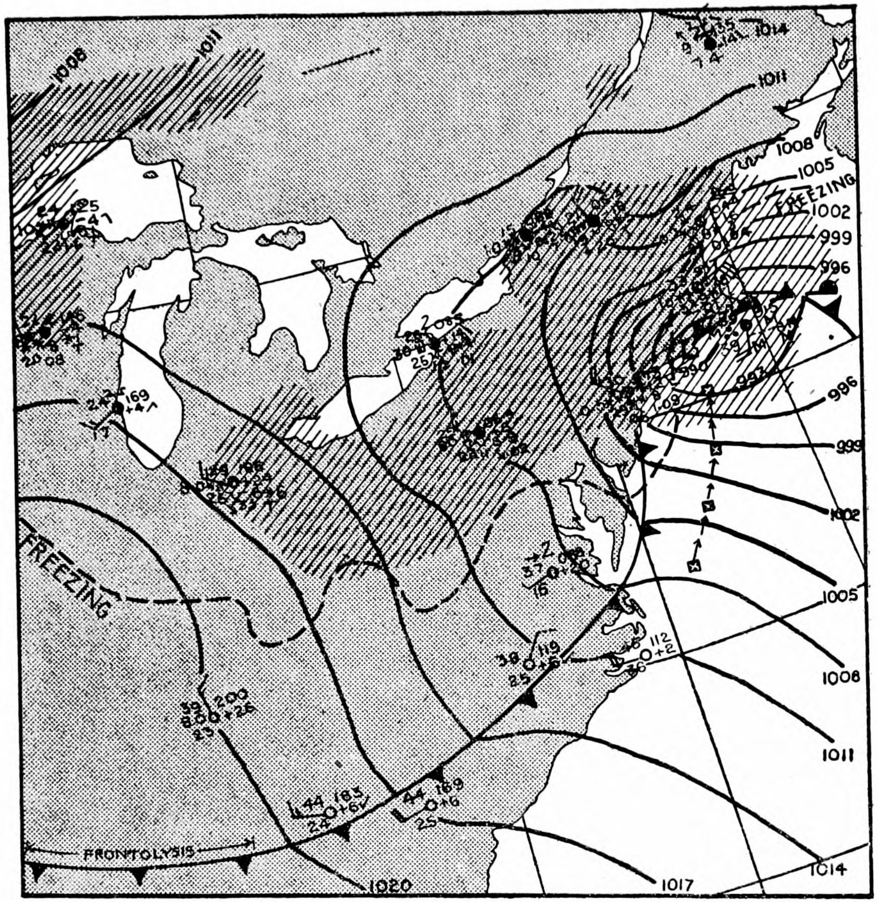

1008
1011
1014
1011
1008
1005
FREEZING
1002
999
996
986
999
1002
1005
1008
1011
1014
1017
1020
FREEZING
FRONTOLYSIS

FIG. 4—SYNOPTIC CHART, 7.30 P.M., E.S.T., DECEMBER 26, 1947
For explanation see Fig. 1.

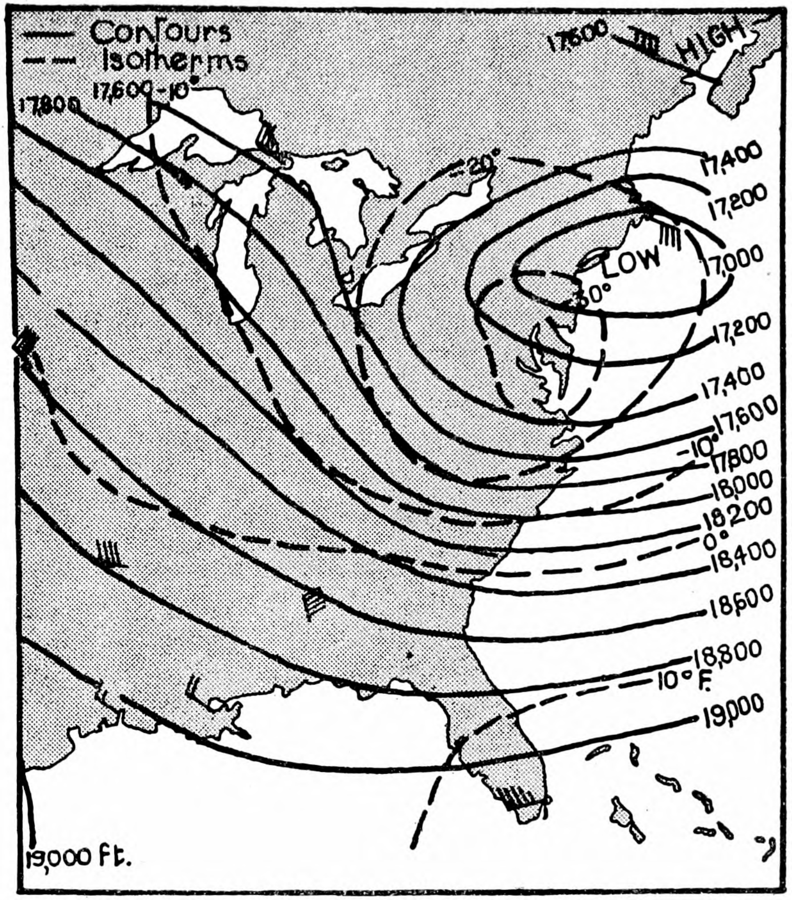

Contours
Isotherms
17,600-10°
17,800
17,600
HIGH
-20°
17,400
17,200
LOW
-30°
17,000
17,200
17,400
17,600
-10°
17,800
18,000
18,200
0°
18,400
18,600
18,800
10°F.
19,000
19,000 ft.

FIG. 5—500-MB. CONSTANT-PRESSURE CHART, 10.30 P.M., E.S.T., DECEMBER 26, 1947

Fig. 4 shows the depression at 7.30 p.m. December 26 centred very near New York with a warm front to the east just along the coast. The temperature difference across the front at the surface seems to have been about 10°F. The tip of the warm sector, round which precipitation was particularly heavy, moved near New York. The depression over the Great Lakes had by this time nearly filled up appearing only as a bulge in the isobars. The centre of low pressure at 500 mb., Fig. 5, was by 10.30 p.m. December 26 roughly over the Atlantic depression.

The wind was below 30 m.p.h. for most of the period of the snowfall reaching a maximum of 30 m.p.h. Temperature was between 24° and 30°F. The whole system looks rather weak for such a heavy fall. It is clear the warm-sector air at a moderate altitude must have been very warm and damp but unfortunately there are no upper air observations from the warm sector. Owing to the relatively light winds drifting, though serious enough with drifts 6 ft. deep, did not produce the 20-ft. drifts of the New York blizzard of March 12, 1888, when both the total fall of snow and rate of fall were much less but the wind exceeded 60 m.p.h. The synoptic situation of the 1888 blizzard, during which temperature fell below 5°F., was similar to the recent one, with a depression developing over the southern Atlantic States moving north-east and then north-north-east apparently under the influence of a depression over the Great Lakes.

OBITUARY

Mrs. A. H. R. Goldie. With deep regret we record the death on February 3, 1948, of Mrs. Goldie, wife of Dr. A. H. R. Goldie, Deputy Director (Research) of the Meteorological Office. To Dr. Goldie we extend the sympathy of all members of the staff of the Meteorological Office in his great loss.

Two friends of Mrs. Goldie, the one closely associated with her at Edinburgh and the second at Stonehouse during the war, have written appreciations which we publish below.

Mrs. Goldie's association with the Office dated back to August 1919 when, as Miss Marion Wilson, she joined the staff of Eskdalemuir Observatory with her friend Miss Graham-Yooll. After working there for a year under Dr. Crichton Mitchell, Superintendent, she was transferred to the newly-established Meteorological Office, Edinburgh, where she remained until her marriage to Dr. Goldie in 1928. Of a charming, friendly and happy disposition, Mrs. Goldie will be remembered by many members of the staff for her kindness and hospitality. One recalls delightful Christmas parties given to the staffs of M.O. Edinburgh and Scottish outstations.

A. E. MURRAY

The death of Mrs. Goldie will be keenly felt by all members of the Marine, Climatology and Instruments Branches who served at Stonehouse. Most of the younger members were billeted in strange homes, and Mrs. Goldie invited them to tea on Sundays, sympathised with their troubles and generally mothered them. I recall with gratitude that in an emergency the Goldies gave me a home for a week, and the same kindness was extended to visitors from London who could not find hotel accommodation. When the canteen arrangements broke down and we decided to become our own caterers, the triumphant success of the experiment was largely due to the energy which Mrs. Goldie put into it, in addition to the work which she was already doing in the British Restaurant at Stroud. In all these ways, the fact that our exile in Gloucestershire was on the whole pleasant and comfortable, was largely due to the efforts of Dr. and Mrs. Goldie to make it so.

C. E. P. BROOKS

REVIEW

A numerical method for the calculation of temperature changes by radiation in the free atmosphere, by A. Bruinenberg. Koninlijk Nederlandsch Meteorologisch Instituut, De Bilt No. 125, Mededelingen en Verhandelingen, Serie B, Deel I. No. 1. Size: 12¼ in. × 8¾ in., pp. 103, *Illus.* 's-Gravenhage, 1947. Dutch with English Summary.

With the great increase in upper air observations the subject of non-adiabatic temperature changes in air masses is coming to the fore as an important problem in synoptic meteorology. Radiation is an example of such a process, and semi-empirical means of calculating the flux of radiation at a given level have been devised, the radiation charts of Mügge and Möller and of Elsasser being perhaps the best known. To compute the heat loss, however, the derivative of the flux is required, and readers familiar with the use of radiation charts will appreciate the difficulty and lack of precision involved in the plotting and estimation of long narrow areas of irregular shape. The greater part of the present memoir is concerned with the development of a direct numerical method for the estimation of the derivative of the flux, and with the presentation of the necessary tables and diagrams.

Chapters are devoted to a general survey of radiation problems, radiation charts—mainly a convenient transformation of the Möller chart, the determination of a change of flux with height by the method mentioned above, and direct heating of the atmosphere by solar radiation. The English summary concentrates on the original part of the work, and adequately explains the method. There are very helpful numerical examples. Tables and diagrams occupy 400 pages and represent a very considerable volume of work by the author.

No meteorologist interested in radiative temperature changes can afford to neglect this work, and the numerical method may prove more convenient than existing graphical ones for some problems. Results however will not be greatly different if the radiation charts are used with care ; the following figures may be quoted for one of the numerical examples. the first two figures being computed by Bruinenberg, the last by the reviewer.

De Bilt March 4, 1938, 1,100 to 1,200 m.
Cooling in 24 hr. (water vapour only)

Transformed Möller chart	1·8°C.
Numerical method	2·4°C.
" Kew " radiation chart	2·2°C.

G. D. ROBINSON

ERRATUM

FEBRUARY 1948, page 31, line 2, equation 14

$$\textit{for}\quad \frac{lH_i}{T_0 - lH_i}\quad \textit{read}\quad \frac{lH_i^2}{T_0 - lH_i}$$

WEATHER OF FEBRUARY 1948

The month opened with a very deep depression in the Atlantic south of Iceland, with a reading of 936 mb. on the 2nd. Weather over the British Isles continued unsettled until about the 14th, when an anticyclone which had lain over eastern and north-central Europe since the 8th spread westwards. By the 16th it was centred over Scandinavia and easterly winds caused a rapid fall of temperature in Great Britain. The anticyclone again moved westwards to a position south-east of Iceland on the 22nd, after which it turned eastwards again to central Europe. For the month as a whole pressure exceeded 1020 mb. over England, southern Scandinavia and most of continental Europe ; another high-pressure area (1025 mb.) lay over New England, while the North Atlantic was occupied by a relatively low area (below 1010 mb.). Pressure was more than 5 mb. above normal over the British Isles, Scandinavia, northern France and the Baltic shores, the excess being 10 mb. over southern Norway, while the central Atlantic between 35° and 55°N. was slightly below normal.

The unsettled, stormy weather experienced in the British Isles throughout January persisted during the first half of February. Gales were reported locally on each day from the 1st-10th, the gale on the 8th-9th being both widespread and severe. The speed in gusts rose to 95 m.p.h. at Durham and 87 m.p.h. at Renfrew on the 9th. Heavy rain occurred in some areas on the 1st, 7th and 8th ; for example, 2.75 in. at Kinlochleven (Argyllshire) on the 1st and 2·97 in. at Bala (Merioneth) on the 8th. A change of type set in on the 15th and subsequently an anticyclone became centred over southern Scandinavia with an extension over the British Isles. Under the influence of this pressure distribution a cold air stream from north-east Europe brought cold, mainly fair weather to this country. On the 20th a cold front moving west over England and Wales was associated with widespread snow and on the 21st small secondaries moving west in the easterly current brought more snow to southern districts. Level snow was 14 in. at Biggin Hill, 11½ in. at Wilmington, Kent and 10 in. at Croydon, while at Hampstead there were drifts of three to four feet. It was very cold over much of England from the 20th-22nd, temperatures remaining continuously below freezing point at some places on the 20th and 21st. The last week was mainly sunny and dry ; except in foggy areas temperature rose on the 28th though the nights continued rather cold. In the southern half of England it was very warm on the 29th, temperatures reaching or exceeding 60° F. at many places. The extreme temperatures for the month were 64°F. at Milford, Surrey on the 29th and 5° F. at East Malling, Kent on the 22nd.

The general character of the weather is shown by the following table :—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	64	5	+0·8	73	−1	96	23
Scotland	55	15	+0·6	109	0	96	22
Northern Ireland ..	57	23	+0·5	81	+4	83	20

RAINFALL OF FEBRUARY 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·40	84	*Glam.*	Cardiff, Penylan ..	2·38	81
Kent	Folkestone, Cherry Gdns.	1·25	62	*Pemb.*	St. Ann's Head ..	1·55	55
,,	Edenbridge, Falconhurst	2·60	118	*Card.*	Aberystwyth	1·05	42
Sussex	Compton, Compton Ho.	1·85	70	*Radnor*	Bir. W. W., Tyrmynydd	4·43	84
,,	Worthing, Beach Ho. Pk.	1·27	64	*Mont.*	Lake Vyrnwy	7·38	166
Hants.	Ventnor, Roy. Nat. Hos.	1·62	77	*Mer.*	Blaenau Festiniog ..	8·20	100
,,	Fordingbridge, Oaklands	1·08	43	*Carn.*	Llandudno	1·24	64
,,	Sherborne St. John ..	1·25	57	*Angl.*	Llanerchymedd ..	1·86	74
Herts.	Royston, Therfield Rec.	·84	55	*I. Man.*	Douglas, Boro' Cem. ..	2·93	92
Bucks.	Slough, Upton ..	1·06	62	*Wigtown*	Port William, Monreith	1·96	64
Oxford	Oxford, Radcliffe ..	·88	54	*Dumf.*	Dumfries, Crichton R.I.	3·48	106
N'hant.	Wellingboro', Swanspool	·91	57	,,	Eskdalemuir Obsy. ..	5·83	118
Essex	Shoeburyness	1·34	109	*Roxb.*	Kelso, Floors	1·64	96
Suffolk	Campsea Ashe, High Ho.	·83	60	*Peebles.*	Stobo Castle	3·45	125
,,	Lowestoft Sec. School ..	·71	51	*Berwick*	Marchmont House ..	1·69	81
,,	Bury St. Ed., Westley H.	1·04	69	*E. Loth.*	North Berwick Res. ..	1·93	124
Norfolk	Sandringham Ho. Gdns.	1·09	66	*Midl'n.*	Edinburgh, Blackf'd. H.	2·14	129
Wilts.	Bishops Cannings ..	1·25	59	*Lanark*	Hamilton W. W., T'nhill	3·99	138
Dorset	Creech Grange.. ..	1·68	59	*Ayr*	Colmonell, Knockdolian	2·11	81
,,	Beaminster, East St. ..	1·68	56	,,	Glen Afton, Ayr San. ..	5·13	117
Devon	Teignmouth, Den Gdns.	1·30	49	*Bute*	Rothesay, Ardencraig ..	5·18	129
,,	Cullompton	2·07	74	*Argyll*	L. Sunart, Glenborrodale	6·17	103
,,	Barnstaple, N. Dev. Ath.	1·17	43	,,	Poltalloch	5·19	120
,,	Okehampton, Uplands	2·67	61	,,	Inveraray Castle ..	9·57	141
Cornwall	Bude School House ..	1·34	54	,,	Islay, Eallabus ..	3·87	92
,,	Penzance, Morrab Gdns.	1·52	46	,,	Tiree	4·40	128
,,	St. Austell, Trevarna ..	1·68	44	*Kinross*	Loch Leven Sluice ..	4·09	145
,,	Scilly, Tresco Abbey ..	1·65	59	*Fife*	Leuchars Airfield ..	2·17	124
Glos.	Cirencester	1·49	66	*Perth*	Loch Dhu	10·90	146
Salop	Church Stretton ..	1·71	73	,,	Crieff, Strathearn Hyd.	5·73	163
,,	Cheswardine Hall ..	1·20	67	,,	Blair Castle Gardens ..	3·90	140
Staffs.	Leek, Wall Grange P.S.	1·78	75	*Angus*	Montrose, Sunnyside ..	2·16	117
Worcs.	Malvern, Free Library	1·11	62	*Aberd.*	Balmoral Castle Gdns...	3·03	117
Warwick	Birmingham, Edgbaston	1·61	95	,,	Dyce, Craibstone ..	1·04	45
Leics.	Thornton Reservoir ..	1·52	91	,,	Fyvie Castle	1·30	58
Lincs.	Boston, Skirbeck ..	·77	53	*Moray*	Gordon Castle	1·03	54
,,	Skegness, Marine Gdns.	1·14	75	*Nairn*	Nairn, Achareidh ..	1·78	110
Notts.	Mansfield, Carr Bank	1·35	70	*Inv's*	Loch Ness, Foyers ..	4·53	139
Ches.	Bidston Observatory ..	1·48	88	,,	Glenquoich	9·18	89
Lancs.	Manchester, Whit. Park	1·84	96	,,	Fort William, Teviot ..	8·51	113
,,	Stonyhurst College ..	3·58	107	,,	Skye, Duntuilm ..	4·43	96
,,	Blackpool	1·95	87	*R. & C.*	Ullapool	3·14	76
Yorks.	Wakefield, Clarence Pk.	1·51	88	,,	Applecross Gardens ..	5·38	107
,,	Hull, Pearson Park ..	1·10	66	,,	Achnashellach	7·66	111
,,	Felixkirk, Mt. St. John	1·12	66	,,	Stornoway Airfield ..	4·52	107
,,	York Museum	1·19	79	*Suth.*	Lairg	2·90	94
,,	Scarborough	1·13	67	,,	Loch More, Achfary ..	6·51	99
,,	Middlesbrough.. ..	·67	52	*Caith.*	Wick Airfield	2·29	101
,,	Baldersdale, Hury Res.	3·63	121	*Shet.*	Lerwick Observatory ..	3·54	112
Norl'd	Newcastle, Leazes Pk.	1·42	93	*Ferm.*	Crom Castle	2·34	80
,,	Bellingham, High Green	2·88	113	*Armagh*	Armagh Observatory ..	1·82	82
,,	Lilburn, Tower Gdns...	1·04	52	*Down*	Seaforde	2·20	72
Cumb.	Geltsdale	2·28	88	*Antrim*	Aldergrove Airfield ..	1·43	59
,,	Keswick, High Hill ..	5·16	104	,,	Ballymena, Harryville..	2·34	72
,,	Ravenglass, The Grove	2·47	80	*Lon.*	Garvagh, Moneydig ..	2·73	87
Mon.	Abergavenny, Larchfield	1·91	60	,,	Londonderry, Creggan	3·15	99
Glam.	Ystalyfera, Wern House	3·97	77	*Tyrone*	Omagh, Edenfel ..	2·99	100

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, OCTOBER 1947

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
	Mean of day M.S.L.	Diff. from normal	Absolute		Mean values							Total	Diff. from normal	Days	Daily mean	Percentage of possible
			Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb							
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hrs.	%
London, Kew Observatory	1022·0	+7·8	70	32	59·5	43·5	51·5	+0·5	48·3	85	7·7	0·15	−[illegible]·55	4	3·0	28
Gibraltar	1017·7	+0·5	84	56	75·3	65·3	70·3	+3·9	66·6	86	5·2	1·64	—	6	—	—
Malta	1016·9	+0·9	82	58	76·4	64·3	70·3	−0·6	67·1	69	5·2	1·28	—	8	7·2	64
St. Helena	1017·0	—	68	52	62·0	53·7	57·9	+0·4	54·1	96	9·6	2·77	+1·46	23	—	—
Freetown, Sierra Leone	1011·9	+1·9	89	70	84·8	73·9	79·3	+0·8	75·0	85	7·9	14·38	+1·76	29	5·9	50
Lagos, Nigeria ..	1012·3	+1·3	91	67	86·7	70·6	78·7	−1·0	76·4	86	8·8	4·16	—	10	4·9	41
Kaduna, Nigeria ..	1010·6	—	93	59	88·9	65·3	77·1	−0·6	72·0	71	6·8	0·87	−1·88	4	7·8	65
Chileka, Nyasaland ..																
Salisbury, Rhodesia ..																
Cape Town ..	1017·4	0·0	83	46	69·2	55·3	62·3	+1·1	56·4	74	5·3	0·79	−0·86	8	—	—
Germiston, South Africa	1013·3	—	89	45	78·7	54·6	66·7	—	54·0	48	3·4	0·88	—	7	9·6	76
Mauritius	1020·5	+2·3	82	62	79·3	65·1	72·2	−0·5	65·1	70	5·2	0·68	−0·99	21	8·3	66
Calcutta, Alipore Obsy.	1009·7	+0·2	95	66	88·9	75·0	81·9	+2·6	75·6	88	5·3	3·27	−1·63	10	6·1	53
Bombay	1010·8	+1·0	93	71	87·6	74·6	81·1	−1·3	74·3	86	2·8	2·92	+1·25	3	8·9	76
Madras	1009·6	+0·7	93	69	88·5	74·6	81·5	−0·8	75·8	84	6·0	11·55	+0·40	16	7·1	60
Colombo, Ceylon ..	1011·5	+1·5	89	70	84·3	74·5	79·4	−1·1	74·8	88	8·2	11·41	−1·95	17	6·1	51
Singapore	1009·5	−0·2	91	72	87·3	74·6	80·9	−0·2	77·4	82	—	6·81	−1·26	21	—	—
Hongkong	1015·4	+1·7	88	65	80·2	70·0	75·1	−1·8	68·3	72	5·0	0·70	−4·24	6	7·7	66
Sydney, N.S.W. ..	1014·5	−0·3	85	48	71·9	55·6	63·7	+0·1	56·4	54	4·5	2·18	−0·67	9	7·6	59
Melbourne	1013·0	−1·8	84	41	65·8	48·3	57·1	−0·6	51·2	59	6·9	4·66	+2·03	19	5·5	42
Adelaide	1015·2	−0·8	87	43	67·1	51·1	59·1	−2·8	52·9	58	7·1	2·77	+1·03	17	5·4	42
Perth, W. Australia ..	1016·1	−0·7	79	40	69·7	50·8	60·3	−0·5	55·7	64	5·0	5·65	+3·43	16	7·6	59
Coolgardie	1014·4	−0·5	91	39	74·5	50·1	62·3	−1·4	51·3	54	2·7	0·69	+0·03	5	—	—
Brisbane	1016·9	+0·7	86	54	76·4	59·1	67·7	−2·1	60·3	63	6·0	3·66	+1·13	11	7·7	61
Hobart, Tasmania ..	1009·3	−1·0	82	37	60·8	45·1	52·9	−1·2	47·9	63	7·9	7·60	+5·34	24	5·9	45
Wellington, N.Z. ..	1011·6	−1·5	70	38	58·8	47·9	53·3	+0·3	50·9	80	8·6	7·61	+3·53	19	4·4	33
Suva, Fiji	1013·1	−0·1	84	63	81·3	70·6	75·9	+0·1	71·3	79	6·5	5·49	−2·80	14	6·7	54
Apia, Samoa ..	1010·6	−0·9	89	68	86·3	73·1	79·7	+1·3	76·1	73	5·8	7·59	+1·21	13	7·3	59
Kingston, Jamaica ..	1011·9	+0·4	93	72	89·6	72·3	80·9	+0·4	76·1	77	3·3	2·32	−5·14	6	8·8	75
Grenada, W. Indies ..	1011·4	+0·6	88	73	87·0	76·4	81·7	+1·6	78·4	80	6·4	4·49	−3·27	27	—	—
Toronto	1020·0	+2·5	79	34	67·0	48·0	57·5	+8·9	48·7	84	4·6	1·12	−1·45	5	7·0	63
Winnipeg	1012·5	−2·4	75	22	60·1	39·9	50·0	+9·3	40·0	82	5·4	1·58	+0·21	10	5·5	51
St. John, N.B. ..	1017·9	+2·1	76	30	60·5	44·0	52·3	+7·0	45·2	84	5·0	0·27	−4·27	6	6·7	61
Victoria, B.C. ..	1010·8	−6·3	73	33	57·1	43·1	50·1	−0·2	46·1	94	7·5	6·03	+3·46	19	3·2	29

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CLASSIFICATION OF CLIMATES

BY C. E. P. BROOKS, D.SC.

The Greek philosophers, observing that the elevation of the sun at noon increased southwards and correctly inferring that this was the cause of the increasing heat, divided that part of the earth's surface which they knew into a series of parallel thermal zones, the most northerly and southerly being uninhabitable because of extreme cold and extreme heat. When instrumental observations began to accumulate in the mid nineteenth century, and climatologists turned again to the classification of climates, this thermal basis was still dominant.[1]* Thus A. Supan[2] (1879) limited the well known " torrid " and " frigid " zones by the mean annual temperature of 20°C. and the mean of 10°C. in the warmest month, and in 1884 W. Köppen's first classification[3] was on similar lines. Meanwhile botanists had likewise been defining zones based on the distribution of different types of plant assemblages, and had realised that between the tropical and temperate zones of humid vegetation, defined by temperature, must be inserted a " desert " zone, defined by lack of rainfall. The idea had also grown up that plants were natural " integrators " of all the climatic elements, especially temperature and moisture, and this led to a formula which tried to incorporate both these elements.

It was quickly realised that the moisture requirement of a plant is greater the higher the temperature. The ideal measure would be the difference between rainfall and free evaporation, but measurements of evaporation are too few and uncertain, and numerous attempts have been made to find an index which could be derived directly from the data readily available. As early as 1869 C. Linsser[4] had expressed the " effective rainfall " as the ratio P/T, where P is the annual precipitation in centimetres and T the mean annual temperature in degrees centigrade. W. Köppen, after experimenting with the numbers of rain days and the ratio of monthly rainfall to saturation deficit, settled down to a formula of the type $P/(aT + c)$, but the values of the constants have varied from one edition of his classification to another. Köppen also realised that the effectiveness of rainfall is greater if it falls in winter than in summer, and in 1923 he defined the limit of the steppe climate as $T + 22$ for winter rains, $T + 33$ for uniform rains and $T + 44$ for summer rains where T is in degrees Centigrade and the rainfall is in centimetres; the limits for the desert climate are half these amounts.

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*These numbers refer to the list of references on p. 100.

A slightly different approach was made by A. Ångström[5] in 1936, based on Van't Hoff's law that the velocity of a chemical reaction approximately doubles for each rise of temperature by 10°C. This gave a moisture coefficient

$$I = P/(1{\cdot}07)^t$$

Van't Hoff's law is of wide applicability in biological as well as chemical action, but in the former there is an optimum temperature above which the speed of action, e.g. rate of growth of plants, falls off.

In recent years the subject has been taken up in great detail by C. W. Thornthwaite[6] who, in 1931, defined " precipitation effectiveness " as

$$\frac{P}{E} = 11{\cdot}5 \left(\frac{P}{T - 10}\right)^{10/9}$$

where P is the precipitation in inches, E the evaporation in inches, and T the temperature in degrees Fahrenheit. In his latest contribution[7], however, Thornthwaite has discarded this form in favour of one which he regards as more logical. His classification has two main indices, which he terms " potential evapotranspiration " and " thermal efficiency ".

Potential evapotranspiration (P.E. or e) is the amount of water which would be used by the vegetation if it were available; it can be measured in a dry basin by finding the amount of irrigation water actually used, or in wetter regions by the difference between rainfall and run-off. In a standard month of 30 days with 12 hours possible sunshine it is given by

$$e = ct^a$$

the coefficients c and a being variable. The method is elaborate; it depends on the computation of a monthly index $i = (t/5)^{1{\cdot}514}$; the summation of the twelve values of i gives the annual heat index I. The coefficients a and c are complicated functions of I. The figures are then corrected for number of days and length of day in the months. The method is purely empirical, designed to fit the few actual measurements of e available in North America.

The basis of the moisture classification is the total balance $R - e$ and its variation throughout the year. He first finds the total surplus of water in the rainy months, and the total deficiency in the dry months, and expresses them in the form

$$I_h = \frac{100s}{n} \qquad I_a = \frac{100d}{n}$$

where s is the water surplus, d the water deficiency and n the water need. These are combined in the form

$$I_m = \frac{100s - 60d}{n}$$

the smaller coefficient of d taking account of the fact that in times of drought plants conserve moisture by reducing transpiration. I_m can range from above 100 to $-$ 60, and this range is divided into nine equal steps, A, B_4, B_3, B_2, B_1, C_2, C_1, D, E, from "perhumid" to "arid". Each of these is subdivided into r, s, w, s_2, w_2, according as the deficiency of water occurs to a moderate or large extent in summer or winter.

The potential evapotranspiration is also an index of thermal efficiency, TE, and stations are again classified into nine TE stages from A′ (megathermal) to E′ (frost) according to the potential evapotranspiration with further subdivisions a′ to d′ according to the annual variation. The complete classification of a climate is therefore fourfold, e.g. San Francisco is $C_1B'_1s_2a'$ or " dry subhumid, first mesothermal, with large winter surplus and a temperature régime normal to megathermal ".

One of the most interesting features of the paper is the method of constructing diagrams of average water need by superposing curves of monthly potential evapotranspiration and monthly rainfall. Water is stored in the soil in times of excess, and drawn on in times of deficit, and Thornthwaite estimates this storage as equivalent to 4 in. (10 cm.) of rainfall, and this is shown in the diagrams. It may be of interest to construct such a diagram for Richmond (Surrey). This is shown in Fig. 1 where the broken line represents the precipitation, adjusted to a mean month of 30·5 days, and the full line the calculated potential evapotranspiration. Vertical shading represents the excess precipitation available for run-off, diagonal shading on the left the utilization of soil moisture and on the right the recharging of the soil. The inference from this diagram is that from mid May to the end of September there is less moisture available than plants can use, and surplus water is only available for run-off from early November to early April, a suprising conclusion. The total *e* for the year comes out as 25·3 in., which is considerably higher than either the evaporation from the tank or the difference between rainfall and run-off, both of which are about 15·5 in.

Actually, in a normal summer there is little or no water shortage in south-east England, and Thornthwaite's formula, developed for the United States, is evidently not applicable to this country without some modification. One source of the error probably lies in the correction for length of day which gives a multiplication factor of 1·37 for the calculated *e* in July. This is certainly too high, for in middle latitudes the greater length of the day in summer with increasing latitude cannot compensate for the lower elevation of the sun. Other sources of error are the amount of cloud at Richmond, which is only partially allowed for by the temperature factor, and the greater relative humidity in England compared with most of the United States.

Thornthwaite's method is interesting, and appears to represent a considerable advance in the calculation of the agricultural possibilities of different climates, but it is evident that he has not yet approached finality. One important element which he has overlooked is the spread of the rainfall over a month, i.e. the number of rain days. Four rainfalls each of 0·5 in. are generally much more effective in providing soil moisture than a single storm of 2-in. rainfall. On the other hand, in summer a number of very light falls do little good. The maximum effectiveness of a summer rainfall probably occurs with daily amounts between 0·25 and 0·75 in. while in winter the limits are lower. Any complete calculation of the water supply available for plants should take account of these facts, for example, by subtracting from the effective rainfall some proportion which depends on the average rainfall in a rainfall day.

The classification of climates grew up as a result of the study of the distribution of plant assemblages, and has also been applied successfully to the study of soil types. In both these cases the effect cannot be expressed numerically by a single figure, and therefore cannot be represented by isopleths. It requires description, and the climatic formula is a convenient shorthand for such a description. Mapping these shorthand descriptions appears to be the only convenient way of setting out the facts. It must be remembered however, that the boundaries between the types are in most cases not sharp lines but transitional areas, and that the more elements brought in, the greater is the complexity of the actual distribution, due to local conditions, and especially the slope and aspect of the land. When it is possible to derive an expression which represents the combined effect of the climatic factors by a single number, as was done for example by Ellsworth Huntington for human energy, it is better to construct isopleths of the numerical values of that expression.

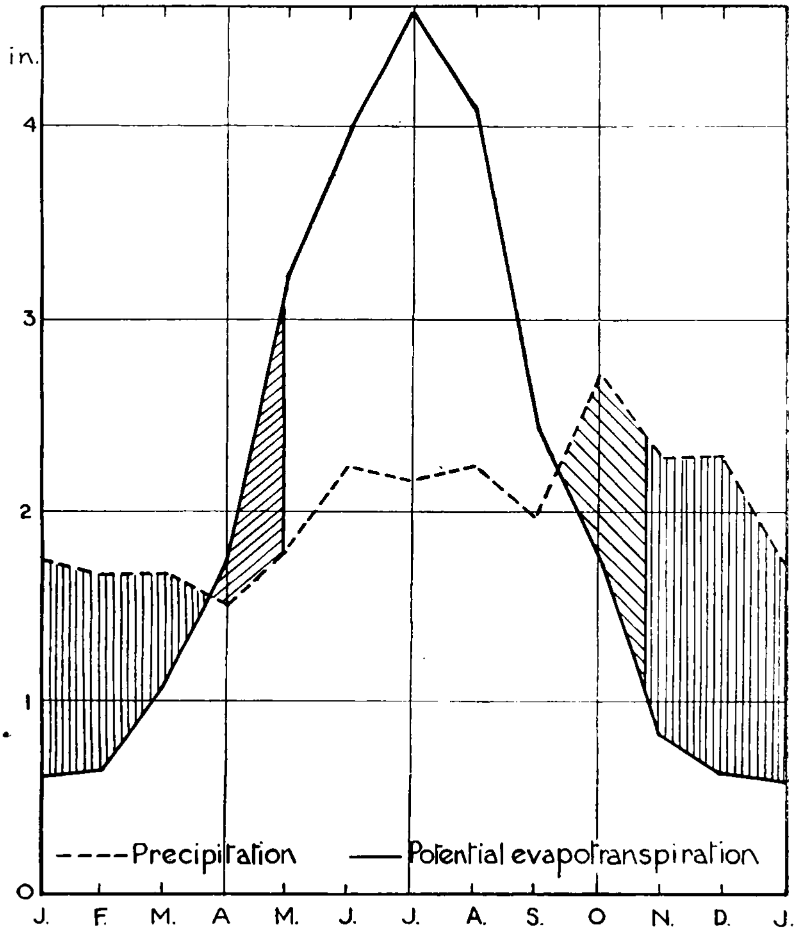

FIG. I—MOISTURE DIAGRAM FOR RICHMOND, SURREY

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SOME ASPECTS OF THE THEORY OF TURBULENCE

BY E. J. SUMNER, B.A.

Part II

Coefficient of eddy diffusivity.—In the foregoing analysis θ is any property which can be associated with an elementary volume of a fluid and which can be thought of as remaining invariant for a limited time following the motion. Also, quoting Brunt[1]*, it must be such that its upward flux has a physical meaning. In the atmosphere the " properties which appear to satisfy these conditions are content of water vapour, dust or carbon dioxide etc., momentum in a fixed azimuth, deviation of temperature from an adiabatic distribution." The expression eddy diffusivity can be used to designate the diffusion of any of these properties, but the processes by which momentum and temperature are transported are often distinguished by the terms eddy viscosity and eddy conductivity respectively.

At one time it was thought that the coefficient of eddy diffusivity K_θ was the same for all properties, and a certain amount of experimental data was forthcoming to support this, but some later evidence is against the hypothesis. As originally defined, K_θ is equal to $\overline{w'l_\theta}$, where l_θ is the transport length of the property in question, that is, the vertical distance moved by an element of fluid to a particular datum level from when it last had a value equal to the mean value of its environment. In the transfer of horizontal momentum, for example, the particle starts with a horizontal velocity equal to the mean velocity at its level, and it is improbable that it simultaneously has acquired the mean temperature, mean moisture content, etc., of its surroundings, so that l_θ would be expected to vary with θ. This does not necessarily mean that $\overline{w'l_\theta}$ depends on the property, but, to say the least, it strongly suggests that conclusion. If, on the other hand, the level of origin of a fluid element is defined as that at which the element was last at rest in the vertical, the transport length is now independent of θ, and may be written without the suffix.

In this case as before, see Part I, equation (5)

$$\begin{aligned} K_\theta &= \overline{w'l} - \frac{\overline{w'\theta''}}{\delta\bar{\theta}/\delta z}, \text{ except when } \frac{\delta\bar{\theta}}{\delta z} = 0, \\ &= K - K'_\theta, \text{ say.} \qquad\qquad .. \quad (6) \end{aligned}$$

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*These numbers refer to the list of references on p. 108.

The value of the coefficient K $(= \overline{w'l})$ is the same for all properties and depends entirely on the dynamics of the eddies, whereas the second expression, K'_θ explicitly recognises the presence of the natural fluctuations in the property, and probably varies with θ. This separation of K_θ into two distinct terms is a definite improvement on the older theories, although there still remains the objection, common to all transport-length theories, that the dependence of l on molecular diffusion is ignored. The sign of K is always positive, while that of K'_θ, for a particular mean gradient, depends on the correlation between the eddy velocity of an element at a given level and of the anomaly of the property when it was last at rest in the vertical. The magnitude of the latter depends on the magnitude of the fluctuations of w' and θ'' and on the mean gradient $\partial\overline{\theta}/\partial z$. It is impossible to find the magnitude of θ'' by direct observation, and, for the time being, it will be assumed that its variations are of the same order of magnitude and similar in character to those of θ'.

The quantity $\overline{w'\theta''}$ is not measurable, but it is interesting to speculate on its possible value for different properties. Considering first of all the eddy conductivity, K_H say, then θ becomes $c_p(T + \Gamma z)$, where T is the absolute temperature, c_p the specific heat at constant pressure and Γ the dry adiabatic lapse rate. Since one would expect warmer parcels of air to show more inclination to rise than colder ones owing to buoyancy and *vice versa*, that is, for w' and T'' to have the same sign ($\overline{w'T''}$ positive), the sign of K'_H depends only on that of

$$\frac{\partial \overline{T}}{\partial z} + \Gamma.$$

For instability $\partial\overline{T}/\partial z$ is negative, and

$$\left|\frac{\partial \overline{T}}{\partial z}\right| > \Gamma,$$

so that the sign of K'_H is negative; and under stable conditions is positive.

This implies that $K_H > K$ for atmospheric instability, which is more often to be found near the ground in day-time, and $K_H < K$ for stability, the average state of the atmosphere away from the surface. For neutral equilibrium $K_H = K$ if sufficient time has elapsed to smooth out the anomalies ($K'_H = 0$). It is assumed throughout that no condensation takes place; for a saturated atmosphere Γ has to be replaced by the moist adiabatic lapse rate.

In the case of momentum transfer, the eddy viscosity, K_M say, is equal to $K - \overline{w'u''}/(\partial\bar{u}/\partial z)$ where u is the horizontal wind velocity. Unless eddies tend to rotate in one direction only it is obvious that there is no more reason why a particle of fluid should approach the datum surface from one direction rather than another, so that $\overline{w'u''}$ should be zero. Although no evidence one way or the other is available, it is suggested as a possibility that eddies do tend to rotate predominantly in one direction (like a wheel) close to the ground, where the horizontal cross-wind component of the mean vorticity ($\partial\bar{u}/\partial z$) is invariably positive. If this is true, and a casual inspection of eddies revealed by smoke drifts suggests that it is, $\overline{w'u''}$ is negative, so that $K_M > K$, and one may hazard the guess that this remains true, on the average, throughout the troposphere, making $K_M > K > K_H$ away from the ground. On account of the inherently greater fluctuations (compared to the corresponding vertical gradient near the ground) of wind velocity than for temperature it is probable even here, that $K_M > K_H$, both being greater than K.

The diffusivity of other atmospheric properties depends on their correlation with those already discussed. Thus any θ which is positively correlated with the temperature T would also have the property that $K_\theta > K$ if its mean gradient, $\partial\bar{\theta}/\partial z$, were negative and *vice versa*. If the explanation, which is given later, of the origin of the fluctuations found in nature is correct, moisture content is such a property for diffusion near the ground. In the free air this correlation is probably very small, and one would expect K to be of the same order as K_θ both being greater than K_H. Summing up, all that can safely be said at the moment is that there are both practical and theoretical reasons for believing the coefficient of eddy viscosity to be greater than the coefficient of eddy conductivity everywhere in the atmosphere, and that eddy diffusivity for moisture content is intermediate in value, except possibly near the ground where it approaches the eddy conductivity and if anything is smaller than it. Petterssen and Swinbank[2] have found that the ratio of K_H to K_M in the free air is about 0·65 on an average, but the analysis on which the calculation is based is not rigorous enough to justify one accepting this value as final. K is, of course, not an absolute constant; it decreases rapidly as the atmosphere becomes more stable owing to decreases in both w' and l, as will be seen later.

The coefficient of eddy diffusivity is not directly measurable, but sufficient indirect evidence exists for a general understanding of its salient features. From a general point of view K_θ is determined by the character of the eddy motion, which includes the shape, size and frequency of the various eddies and their absolute and relative motion, an idea that is not amenable to mathematical analysis. It is known to increase rapidly with height above the ground, from a value very close to the coefficient of molecular diffusion to one thousands of times greater a few metres up. After a few hundred metres the rate of increase must fall off and ultimately its value probably decreases again. Its law of increase appears to be nearly linear from a few centimetres above the surface to a hundred metres or so, but it increases more rapidly than linearly in unstable atmospheres and less rapidly in inversions. The absolute value of the diffusivity also depends on the lapse of temperature, being very large for instability and very small for inversions, and it varies to a less extent with the surface roughness of the ground and with the mean wind velocity. This dependence of K_θ on circumstances has been known for a long time, but Priestley and Swinbank[3] have made the novel suggestion that the second term in equation (6) may entirely swamp the first in certain synoptic situations so that K_θ may occasionally be negative, that is, a property—especially, and perhaps only, in the case of temperature—may be transported against the gradient. As the authors point out, the average lapse of temperature away from the earth's surface is such that the potential temperature increases with height whereas mechanical turbulence, according to the earlier ideas, constitutes a powerful agency tending to equalise it. This, and other more factual evidence, which they produce, does support the idea. They go on to say that the approximate balance between the two terms of the flux equation " may account for the ability of radiative processes to dominate the heat transfer, and so achieve the isothermal state characteristic of the lower stratosphere, whereas mechanical turbulence would cause a decrease of temperature with height." At all events the coefficient of eddy diffusivity and the flux may be rather smaller in certain situations than considerations of temperature lapse, etc., would lead one to suppose.

Mass transport.—The atmosphere almost invariably contains solid and liquid particles, and if they are concentrated enough in a particular locality the process of eddy diffusion becomes visible. It is convenient to distinguish between the transport of mass (smoke, dust, spores, water and ice particles) and the less tangible entities previously discussed, in order to illustrate several points hitherto glossed over, and because there are some genuine differences. In the first place the particles may be sufficiently large to have a finite velocity of fall relative to the moving air, and the theory does not apply without modifications. One may instance the settling out of smuts and dust, or the extreme case of the formation of a hailstone. If the particles are small enough to remain in suspension, the transport-length approach is a very good approximation. It is not exactly true, however, since there will always be a small amount of relative motion between the air and the suspended matter, while the smallest particles will be subject to a Brownian movement analogous to molecular diffusion for the other properties.

It is, however, in considering the diffusion of a mass which originates in a limited space and whose rate of emission is independent of the state of the atmosphere, a smoke puff for example, that the main difficulty arises. Here, sideways diffusion is just as important as upwards diffusion and cannot be ignored. Another complication is the size of the cloud of particles, since it is a fact of observation that a small puff of smoke begins to diffuse under the influence of the smaller eddies at first and the initial enlargement is not very great, but later, as the individual particles become more separated, their relative motion is influenced by larger and larger disturbances, and the rate of growth increases accordingly. In other words the eddy diffusivity is a function of the size of the diffusing cluster. For a more detailed account of this point the reader is referred to original papers by L. F. Richardson[4] and O. G. Sutton[5]. If we consider an infinite number of diffusing clusters, all interacting, which is virtually the state of affairs existing in other régimes, this effect evens out and it is permissible to consider the diffusivity as a function of position as distinct from separation. In practice the dependence of eddy diffusivity on the size and motion of the individual eddies is empirically resolved into considerations of temperature lapse, surface roughness, wind velocity, velocity profile and so on.

Atmospheric fluctuations.—The fact and the importance of the fluctuations of atmospheric properties is now well established, and some explanation of their origin must form an integral part of any theory of turbulence. For wind velocity, the eddy velocities may, at times, be almost equal in magnitude to the mean value $\bar{u}$, although the average value of u' is only about 15 per cent. of the mean (Best[6]). The cause of these eddies is still something of a mystery; topographical effects, surface friction, buoyancy and viscous forces are all involved; but, taking the atmosphere as we find it, this almost continual activity must be reflected in other atmospheric properties. If such a property were conserved indefinitely during the motion as envisaged by transport-length theories enormous local variations of θ would result. However, molecular diffusion is constantly striving to destroy the anomalies; it is only the fact that molecular diffusion is slow by comparison with eddy diffusion that makes them at all possible. For general interest a temperature trace typical of the type of synoptic situation described is given in Fig. 1.

It was taken from the original paper by Priestley and Swinbank, and was recorded by means of a special sensitive thermocouple with very little lag, an initial difference of temperature between instrument and atmosphere being reduced by 90 per cent. in 5 seconds. The variations show a distinct period of about two minutes with a maximum amplitude of about 2·5°C., which would be faithfully reproduced by the instrument, and numerous minor fluctuations of a period of 5–10 seconds, about 0·5°C. in amplitude—occasionally much more—which would only represent about half the true amplitude, so

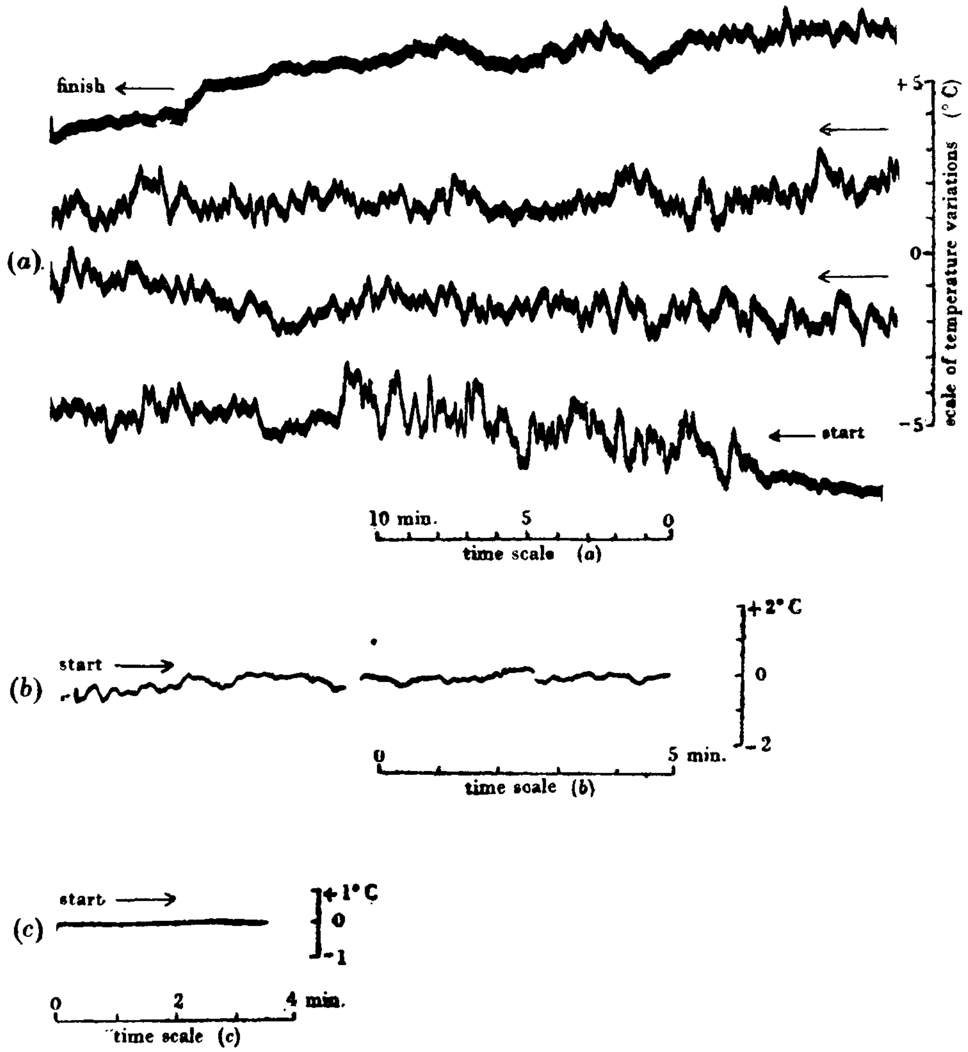

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FIG. 1—VARIATION OF TEMPERATURE

Recorded by a sensitive thermocouple thermograph at Cardington, Bedfordshire, (*a*) at 4 ft. 6 in. above ground, 1450 to 1650 G.M.T. June 27, 1945, with air in rear of cold front, northerly wind 6–10 m.p.h., variable amounts of cumuliform cloud, 9 tenths at start, clearing gradually to 5 tenths; (*b*) at 3,700 ft., 1500 G.M.T. on August 3, 1945, a clear, hot summer afternoon with little wind; (*c*) at 3,000 ft., 1400 G.M.T. on September 11, 1945, dull and overcast with moderate southerly winds (marked advective cooling of air).

that an absolute range of about 3·5°C. is entailed. The authors are of the opinion that it is impossible to explain these fluctuations without postulating transport lengths of several hundreds of feet. Calculations are supplied indicating that temperature excesses as large as those observed would not survive such a long journey, and in any case, observations on drifting smoke near the ground fail to produce a travel of more than a few feet.

A full discussion of these ideas cannot be given here, but it seems that the magnitude of the fluctuations is quite consistent with small transport lengths. Best (*loc. cit.*) found that the average maximum difference of temperature in June (averaged over a period of 20 min.) between 2·5 cm. and 1·2 m. above closely cropped grass, was about 3·4°C. This value, which was for clear skies only, occurred about midday, and was for winds of 5 m.p.h. or thereabouts. Since the instrument used was nothing like sensitive enough to record fluctuations of the order of a few seconds it is practically certain that differences considerably in excess of 3·4°C. do occur and there is no difficulty in explaining by transport alone the microvariations at 4·5 ft. of 1°C. or so, recorded in Fig. 1. The conditions under which the trace was taken, namely cold air in the rear of a front being advected over a relatively warm ground in mid afternoon, makes the existence of a steep lapse rate near the surface very likely in spite of the variable cloud cover. The general impression one gets in studying the curve is of large eddies, 40–50 ft. apart, penetrating right down to, or originating from, the earth's surface and transporting temperature anomalies of the order of 0·5–1·0°C. (occasionally larger) to the datum level, and a continuously diminishing series of smaller eddies and smaller temperature fluctuations fading beyond the perception of the instrument, the whole being superimposed on broader, less erratic, variations reaching a maximum over 300–400 yd. due to the vagaries of track and past history of the air passing over the point of observation. Although these latter are not quite so obviously associated with individual eddies it is probable that large-scale convection modifies the vertical temperature gradient selectively with a consequent local accumulation of heat over such distances, and it will be noticed that as the afternoon advances there is a tendency for these periodicities to disappear. The smaller ones also have a considerably reduced amplitude with time as would be expected since the temperature lapse decreases after midday. However, the whole question of the space scale of atmospheric fluctuations horizontally as compared with the size of eddies, and their relationship to variations at a fixed point of observation, is one for further investigation.

Large temperature lapses near the ground are usually associated with steep moisture gradients, and one would therefore expect temperature and moisture excesses or deficits to appear simultaneously at the datum level on the above theory, and consequently for positive correlation between temperature and moisture content to exist near the ground. This may only be significant when some eddies, at least, originate at the surface as " bubbles " under the influence of buoyancy forces. In other circumstances and for other properties the correlation is probably small, but little is known about the subject. Another gap in our knowledge is the variation of the fluctuations with height, and their frequency distribution. They evidently increase rapidly in amplitude from the surface up to a few metres and then decrease steadily again. Aircraft reports indicate, however, that intense turbulent activity can occur at great heights, even out of cloud, and fluctuations in the other properties are also to be expected near temperature inversions or near discontinuities of moisture and smoke.

Finally, it should be pointed out that the assumption about the magnitude and character of the anomalies θ' and θ'' may not be strictly true in all cases. In Part I the following approximate equation was deduced, viz., $\theta' = -l\partial\bar{\theta}/\partial z + \theta''$ so that, taking means over a large number of fluid elements, we get

$$\overline{\theta'} = 0 = -\bar{l}\frac{\partial\bar{\theta}}{\partial z} + \overline{\theta''}.$$

For $\overline{\theta''}$ to disappear either $\bar{l}$ or $\partial\bar{\theta}/\partial z$ must be equal to zero;* the latter is a special case which seldom occurs. Now it is quite conceivable that elements originating on one side of the datum surface may, in general, have much larger transport length than those coming from the other, so that $\bar{l}$ is not equal to zero, and neither is $\overline{\theta''}$, which implies a different sort of distribution of θ'' from that of θ'; probably neither is symmetrical about the mean value. An example of this is the streaming of air from a heated surface under conditions of light winds and great instability, in which case $\bar{l} > 0$, and $\overline{\theta''} < 0$. Convection in general presents a similar picture, in which upward transport has a longer fetch than downward transport. However, in strong winds with vigorous mechanical turbulence, the assumption seems reasonable enough; the absence of marked convection in high winds is well known.

Pressure fluctuations.—Pressure is another element which is constantly varying and although the variations are small they are of considerable importance in the theory of turbulence since they may influence the vertical transport of momentum. An elementary volume of fluid can be brought to rest horizontally by the shifting pressure gradients long before it has lost its excess temperature, say, or can retain its excess velocity long after. The average effect is unknown, but it was such considerations that led G. I. Taylor[7,8] to suggest that vorticity, which is unaffected by the local variations of pressure in two-dimensional flow, and not momentum is conserved during the motion, and the relative merit of the two approaches has still not been decided conclusively.

Pressure changes in a compressible fluid produce corresponding changes of temperature whose frequency should form a continuous spectrum from one every few minutes to thousands per second corresponding to sound vibrations, but their effect on the eddy diffusivity may even out in the long run. It would be interesting to correlate pressure with temperature for these micro-variations, and to determine the contribution of the variations of the former to those of the latter, but such an event must await the development of suitable instruments. The largest fluctuations in temperature are presumably due to mixing, compression and differential surface heating operating simultaneously. Since they are, apparently, not entirely caused by eddy motion the expression " temperature anomaly " was adopted instead of " eddy temperature " in Part I. For other properties, in view of the absence of any obvious correlation between them and the eddy velocity, and for more general usage, a similar nomenclature is preferred.

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*If terms such as $l^2\partial^2\bar{\theta}/\partial z^2$ are included for exactness, the argument still applies; in fact, the discrepancy is worse when $\partial^2\bar{\theta}/\partial z^2$ is positive.

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AUSTRALASIAN ANTARCTIC EXPEDITION, 1911–14*

Under the leadership of Sir Douglas Mawson

Meteorological data from this expedition have already been published in volumes III, IV and V of this series many years ago (1929–39) and widely used in the technical literature on Antarctic meteorology. For geographical details the reader may refer to another earlier volume (Series A, Vol. I, 1942), which is copiously illustrated. The appearance of these further volumes devoted to theoretical discussion and interpretation by so eminent a meteorologist as Dr. Kidson, whose lead in the introduction of modern Norwegian methods of analysis in Australia and New Zealand is well known, will be of interest to all who follow this branch of the subject and to others concerned with the geographical and glaciological problems of the Far South.

Dr. Kidson was well fitted to undertake this work through long years of interest in Antarctic meteorology as well as through his official contacts as Director of the Meteorological Office of his native New Zealand and in earlier years in Europe, the United States and Australia. His outstanding ability in terrestrial physics was acknowledged in his election as a Fellow of the Royal Society of New Zealand. At the date of his untimely death in 1939, his work, which is reviewed here, was almost finished except for an introductory chapter, which has been deliberately left untouched.

The observation bases established by this expedition were near the coast of Antarctica in 95°E., on the edge of the Shackleton ice-shelf just seaward of the Queen Mary Land coast, and in 143°E. amongst some rock outcrops in Commonwealth Bay, Adélie Land, at the foot of the great Antarctic ice-cap, and on Macquarie Island in the Southern Ocean at 54°S. 159°E. The observations cover 11½, 22½ and 35 months respectively at these stations; a gap in the Macquarie Island series in 1914 was caused by the tragic disappearance of the relieving ship with all hands. For the twelve months covered by the daily weather charts, observations were also available from Scott's base at Cape Evans in the Ross Sea and from the various voyages of the expedition ships *Aurora* and *Terra Nova*.

Some readers will find the retention of the original units of pressure in inches of mercury and temperatures in degrees Fahrenheit awkward in making com-

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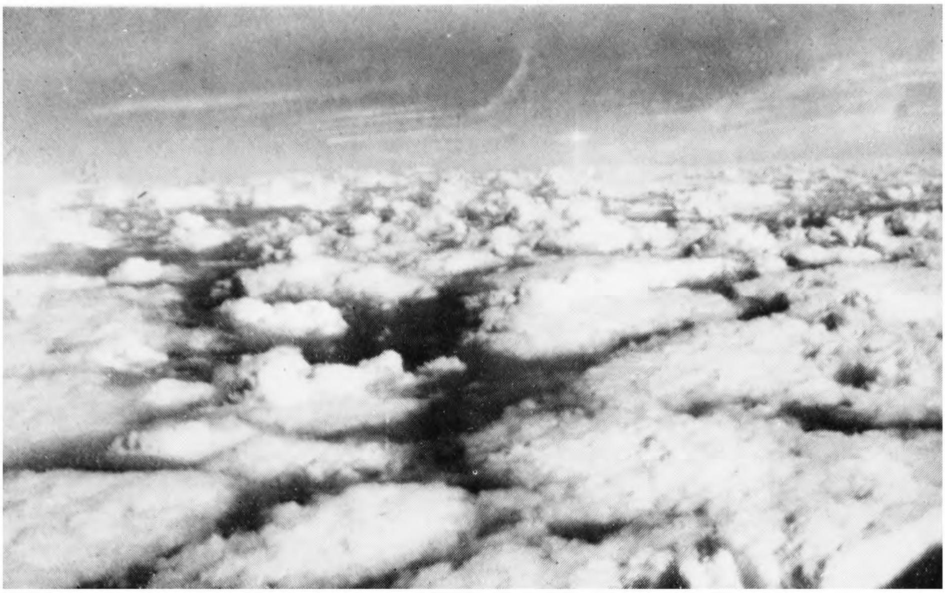
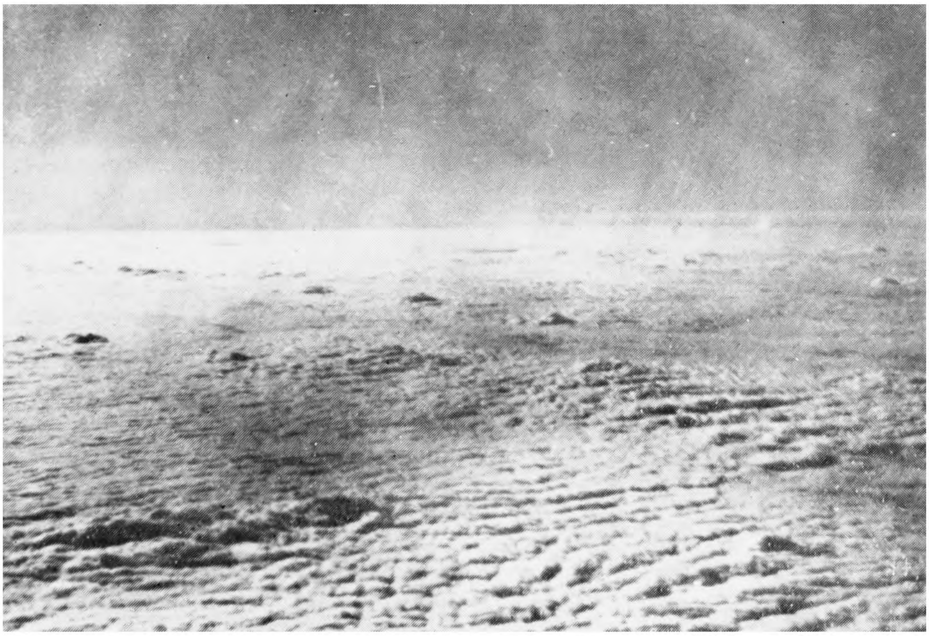
*Scientific Reports, Series B, Vol. VI; *Discussion of observations*, by E. Kidson. 8vo. 12 in × 9½ in., pp. 121, *Illus.* and Vol. VII: *Daily weather charts*, by E. Kidson. 8vo. 12 in. × 9½ in., pp. 31, *Illus.*, including 365 charts. Tennant, Government printer, Sidney, New South Wales. 1946 and 1947. Price 20*s.* and 40*s.*



Photograph by R.A.F.

CUMULUS TOPS SPREADING OUT INTO ALTOCUMULUS

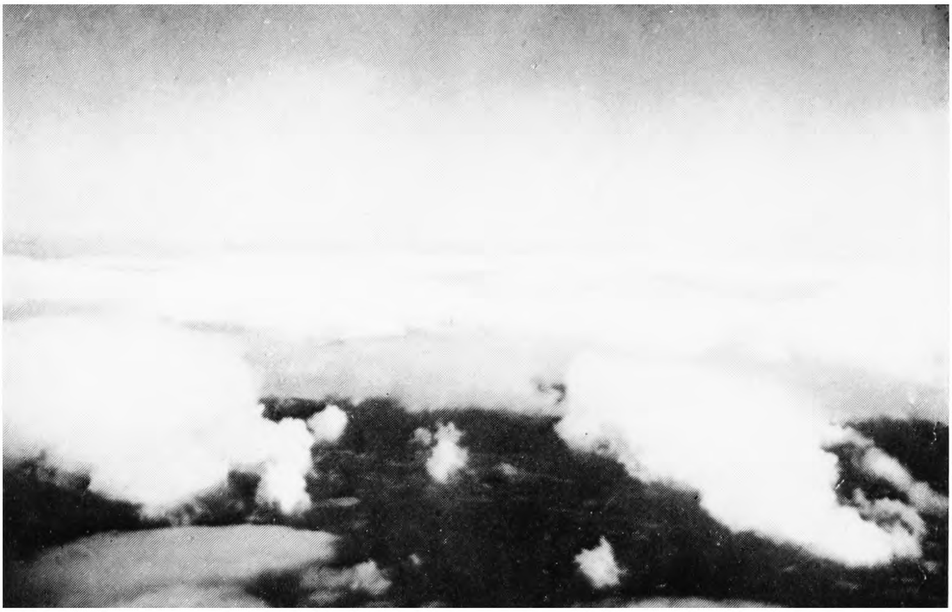
Taken from 29,000 ft. over 40° 45′ N. 05° 20′ E., 1222, September 22, 1943.



Photograph by R.A.F.

LAYER OF ALTOCUMULUS WITH CUMULUS TOPS PROTRUDING

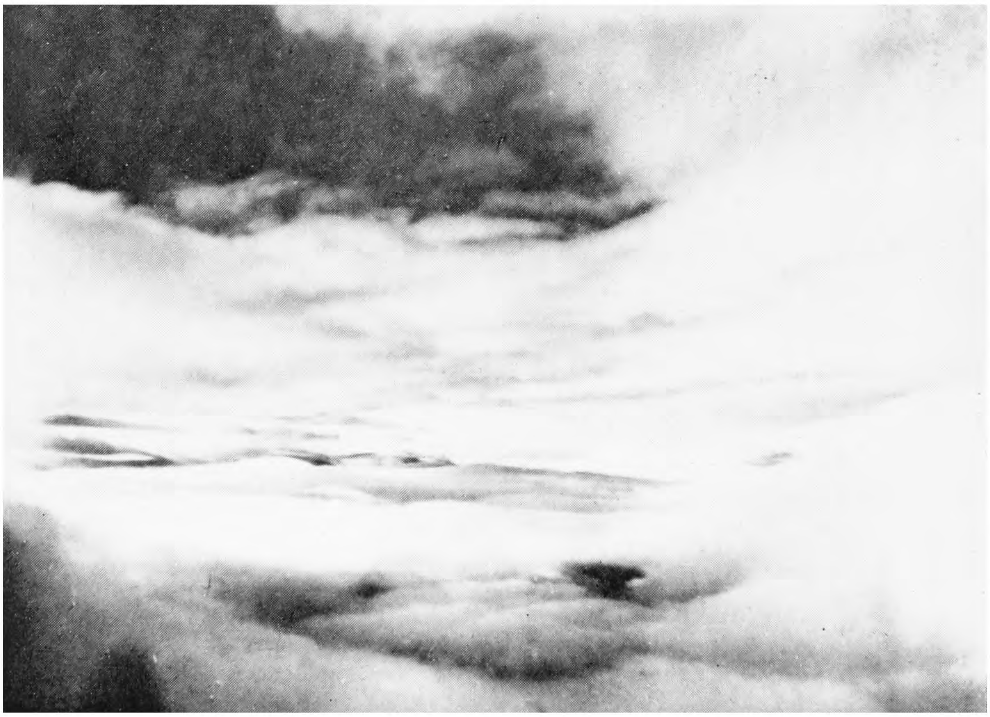
Taken from 29,000 ft., over Montides, 1515, October 2, 1943.



Photograph by R.A.F.

STRATOCUMULUS

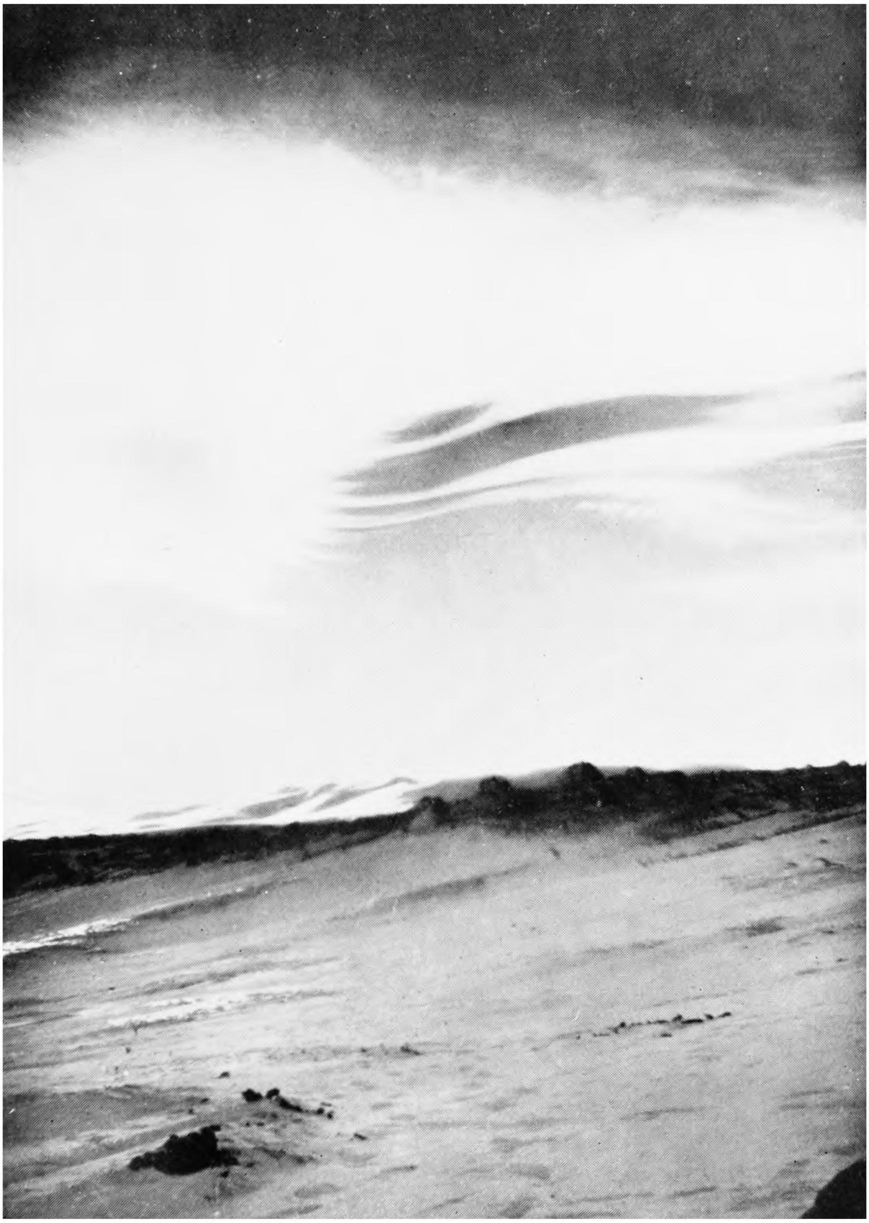
Taken from 9,000 ft. looking north-west over Lancashire (53° 30′ N. 2° 40′ W.) at 1118, July 27, 1945.



Photograph by R.A.F.

A NARROW LANE BETWEEN TWO LAYERS OF STRATOCUMULUS

Taken from 6,000 ft. looking north-east over Oxford, June 2, 1944.



WAVE FORM OF CLOUDS IN THE LEE OF MT. EREBUS, AT SCOTT'S BASE IN THE ANTARCTIC, OCTOBER 22, 1911

MOUNT EREBUS IN THE ANTARCTIC, OCTOBER 22, 1911

EREBUS SMOKE, SEPTEMBER 26, 1912

parisons. The isobar spacing on the charts of one tenth of an inch corresponds to about 3·4 mb.

The actual values, having been published earlier, add nothing new, though Kidson's comments are interesting. Macquarie Island's mean temperature (39·8°F.) is slightly above the average for the latitude in the southern hemisphere, whereas Kerguelen (38°F.) in 49½°S. 70°E. (Indian Ocean sector) is decidedly cold and points in 65°S. west of Graham Land have given temperatures which are decidedly warm for their latitudes. The differences between different longitudes in the southern hemisphere are greater than has often been supposed, and Kidson remarks (Vol. VII, p. 17): " Over the southern hemisphere as a whole . . . the symmetry (of the general atmospheric circulation), though much greater than in the northern, is far from perfect." This awareness of longitudinal differences in climate comes to light in Kidson's discussion of the temperature conditions favouring glaciation in Kerguelen and elsewhere. Another symptom is the prevailing north-westerly winds at Macquarie Island and the relative absence of icebergs in that sector of the Southern Ocean, south of the Tasman Sea. The north-westerly stream of warm air sweeping around the southern side of the South Australian and Tasmanian anticyclones is now believed to steer the frontal storms in this sector, which is one of the stormiest in the Southern Ocean, south-east towards the Wilkes Land coast and into the Ross Sea; it is a sector where the pack-ice fringe off the coast of Antarctica is exceptionally narrow; and at Commonwealth Bay, thanks partly to the fierce katabatic gales affecting the actual shore, there is open water right up to the coast at all times of the year.

The generally low level of atmospheric pressure everywhere in the Far South is amply borne out by these expedition results (means: 986·5 mb. at Queen Mary Land base, 988·2 mb. at Commonwealth Bay, and 998·7 mb. at Macquarie Island), and Kidson considers that the absolute maximum of 1030·5 mb. at Commonwealth Bay was probably unusually high. The highest pressure in four years at Scott's base (77½°S. 166½°E.) in the Ross Sea was 1024·4 mb. The lowest values recorded were about 940 mb. at each station.

The anticyclonic series which gave the 1030 mb. reading at Commonwealth Bay between September 1 and 3, 1912, is one of the most interesting to follow amongst Kidson's charts in Volume VII, showing how a subtropical centre of high pressure moved south or south by west on an abnormal track from eastern Australia directly towards this Antarctic station; but one is left with the impression that this centre more likely went on farther south and south-west into Antarctica instead of collapsing and vanishing eastwards as shown by Kidson on the 4th and 5th. This revision is suggested by the continuance of generally high pressures over Antarctica for the rest of that month, and indeed the following days show no westerly wind at the Queen Mary Land base and no northerly wind at Scott's base, where even the volcanic smoke of Mt. Erebus at 13,000 ft. was drifting from west, south-west or south until the 8th.

Diurnal pressure variations were detected by Kidson using harmonic analysis, the 24-hour term amounting to 0·04 mb. at Commonwealth Bay, 0·05 mb. at Scott's base, 0·17 mb. at Queen Mary Land and 0·68 mb. at Macquarie Island. Data were hardly adequate for any analysis of annual variation of pressure, but Kidson's discussion of the total pressure gradient over the width of the Southern

Ocean between Tasmania and Adélie Land reaching its maximum in October and then falling off rapidly to give the quietest conditions of the whole year in late November and December fits the known facts.

Of aperiodic variations it may be noted that Kidson discovered a tendency for the culminating maximum of pressure at Macquarie Island with the passage of Australasian anticyclones to come about the time of the evening diurnal maximum. This may be of importance in the general study of anticyclones. The greatest changes of pressure in 24 hours were rises of 55 mb. at Macquarie Island and 41 mb. at Commonwealth Bay.

There is some discussion of Simpson's theory of Antarctic pressure surges. Kidson stresses the difficulty of applying periodogram analysis to barograms, since waves of small amplitude may be missed, especially during summer when the amplitude is normally small. The results of such trials are not very convincing. For the Queen Mary Land base it is possible to deduce mean periods of pressure surges of 115 or 153 hr. according to choice, the latter figure actually agreeing with Simpson's figure for Scott's base at McMurdo Sound. Similar results can be got from the Adélie Land records, whilst for Macquarie Island periods of 136 or 183 hr. might be deduced. These figures are quite comparable with the mean period between successive anticyclones over Australia or Bergeron's figure for the frequency of rejuvenation of the Azores high. All such computations of averages however are liable to be confused and rendered inaccurate by the inclusion of non-anticyclonic periods and abnormal situations of some length. On the whole it seems that the pressure changes in the Antarctic dovetail with the frontal processes of depressions moving over the Southern Ocean and are in some way complementary to the anticyclonic developments in the subtropical high-pressure cells which steer the depressions. Kidson's remark is that " while agreeing in the main with Simpson's description of the actual processes I do not think it necessary to introduce a new type of pressure wave . . ."; and this will probably be the experience of any who visit those regions and apply modern forecasting techniques in them.

Commenting on the cloud observations Kidson draws attention to the frequency of lenticular cloud observations near the coast of Antarctica. He points the finger of doubt however at the rather frequent observations of cumulonimbus, saying (p. 99, Vol. VI) that " these clearly do not refer to true cumulonimbus . . ."; in this Kidson is almost certainly wrong, since large cumulonimbus is frequently seen by the whaling ships near the coast of Antarctica and tops estimated at 17,000–20,000 ft. are recorded in the *Balaena* observations (1946–7) at the coast in 112°E. Our theories of Antarctic weather must be adjusted, if need be, to take account of this fact. Cumulonimbus phenomena were expectedly frequent at Macquarie Island, where hail fell on over 80 days a year. The island has a dismal climate, which is fairly typical of the " fifty " latitudes in the Southern Ocean: 63 per cent. of the observations gave overcast skies, mostly with cloud on the hills, of which the highest reached about 1,400 ft.; its annual sunshine total of 380 hr. contrasted with 1,530 hr. at Adélie Land.

The most impressive figures among the observations are undoubtedly those for wind at Commonwealth Bay. These fierce katabatic winds, which blow almost constantly from S'E. and gave an annual mean of 42·9 m.p.h., must be partly controlled by topographical convergence. Much has been written about this place as the " home of the blizzard ", yet it is strange how little description is to be found of any topographical feature which could cause funnelling. Nevertheless it is stated that the observed wind strengths were stronger than is believed to be typical even of this stretch of the coast. It is probable that the explanation must rest in part upon the unknown geography of the interior. The strength and persistence of these winds and the prevalent drift of the lower cloud, also from south-east, do not favour the idea expressed in the charts that depressions commonly pass inland over this station and cross Victoria Land into the Ross Sea, although there are some grounds for thinking that depressions occasionally cross the coast elsewhere.

In an interesting discussion of the difficulties of measurement and estimation of snowfall over Antarctica, Kidson wisely avoids any method based on the assumption that the amount accumulating must be equal to the amount of ice carried out to sea. Such an assumption would ignore the evident wasting of the ice-cap now going on. By another method of estimation Kidson arrives at about 4-in. equivalent rainfall per annum as a typical figure for the coastal regions of Antarctica and slopes below 2 Km. This figure is of the same order as measurements made by more orthodox methods on whaling ships operating near the coast in the summer season and figures obtained for north-east Greenland. In the high interior precipitation must be less. No rain at all fell at Commonwealth Bay, though frozen rain or drizzle was not uncommon; rain is not unknown in some other parts of Antarctica.

The charts in Volume VII are so extremely good in their tropical and subtropical sections over Australasia, where the detailed frontal analysis of tropical cyclones is both new and convincing, that one hesitates to say that the sections over the Southern Ocean and Antarctica are less convincing. One does feel however that the more recent work of Palmer and Ramage* on these regions is really more successful than Kidson's pioneering attempt. Kidson was unfortunate in his assumption, however natural at first sight, that systems affecting Queen Mary Land in 95°E. must eventually affect the bases farther east. We now have evidence of a distinct change of régime in the atmospheric circulation in the higher southern latitudes east and west of about the hundredth meridian. Points west of 100°E. come under the influence of systems circulating southwards from the Indian Ocean and often recurving towards the west in their latter stages. Kidson made it a basic assumption that such westward components of motion could never arise in the Far South. He also seems to have gone too far in deliberately ignoring the katabatic winds and airflow within the Antarctic continental air masses in drawing his isobars over the coastal regions and interior. These air masses are not always shallow, and balloon and nephoscope upper-wind observations show that the easterly wind components which prevail in the surface winds at the coast sometimes reach up to over 10,000 ft. both in anticyclonic and cyclonic situations.

In spite of these criticisms the importance of Dr. Kidson's pioneering effort in the application of normal circulation theories and methods of analysis to the Antarctic must be recognised. This approach is now generally employed.

H. H. LAMB

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*PALMER, C. E.; Synoptic analysis over the southern oceans. *Prof. Notes N.Z. met. Off., Wellington,* No. 1, 1942.

RAMAGE, C. S.; The atmospheric circulation of the Ross Sea area. *Prof. Notes N.Z. met. Off., Wellington,* No. 2, 1944.

METEOROLOGICAL OFFICE DISCUSSION

The Meteorological Office's Monday evening discussion on March 22 was devoted to the consideration of a paper entitled " The influences of shelterbelts on the microclimate of the adjoining territory " by B. A. Bodrov*. The discussion was opened by Mr. R. W. Gloyne who, after pointing out that the paper dealt with some observations taken in the months of July and August during two years over an area with uniform topography near Saratov, sketched briefly the type of meteorological problems which arise in studies of phenomena of this nature. The subject is of fundamental importance in semi-arid regions and is directly related to methods of controlling soil erosion.

After explaining the lay-out of the experiment and the various control and calibration tests undertaken, the influence of a shelterbelt on the wind velocity, temperature, humidity, and evaporation from open water surfaces in the " protected " zone was illustrated by graphs constructed from the original data. The very appreciable percentage reduction in wind velocity for a distance leeward of about 30 times the height of the belt was evident, as were also the " second-order " effects introduced by the absolute value of the particular meteorological element, the height of the barrier and the degree of permeability or penetrability offered by the belt to the airflow. There was evidence also that in certain circumstances measurable effects were to be found at far greater distances from the belt (up to 100 times its height or more).

It was chiefly, however, in the effects on evaporation (as measured by the loss of water from an exposed free surface in a small evaporimeter) that the effectiveness (or " efficiency ") of a shelter belt can be most clearly demonstrated, and these results were held to explain the marked increase in crop yields obtained in semi-arid areas by utilising the protective properties of belts of closely planted trees.

The Director in throwing open the meeting to discussion emphasised the great opportunities presented to the meteorologist in the field of agricultural science, opportunities which so far had been inadequately taken in this country, and he went on to suggest as a typical problem the determination of the effect of unit change in any chosen climatic element on the rate of growth, etc., of field crops. With Dr. Brooks, who pointed out that the Climatological Branch are now making plans for investigation in eco-climatology, the Director expressed surprise at the magnitude of the effects recorded in the paper. Mr. Hogg commented on the fact that with so many variables it was desirable to isolate and study one at a time, and was particularly concerned at the complexities introduced by the very varied crop cover over the area chosen for investigation. Dr. Glasspoole considered in some detail the variations in the catch of a rain-gauge under different conditions of exposure, whilst Dr. Robinson inquired whether the increased moisture evident in the protected zone was at the expense of neighbouring protected areas. Mr. Drummond then pointed out that the extent of the instrumental variance recorded in control tests rendered the results obtained for humidity of somewhat doubtful significance, and Mr. Sawyer suggested that the higher humidity in the protected zone might be attributable to a greater drain on soil moisture reserve due to the increased transpiration in the more turbulent air flow to the lee of the barrier, and finally Mr. Crawford stressed the need for well-planned experimental designs for work of this nature.

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*A publication of the All Union Scientific Research Institute on silviculture and improvement of farmland by forestation, Moscow, 1935. English abstract by R. W. Gloyne, London, 1948.

In the course of the discussion and in his closing remarks Mr. Gloyne agreed that it would be unjustifiable to generalise too readily from the results obtained in one type of climate and with one type of experimental lay-out. It was, however, true that investigational work elsewhere (particularly in the U.S.A.) gave effects of the same order of magnitude; but on the other hand he fully agreed that many carefully designed experiments under our conditions were essential before we could speak with confidence concerning the effects of similar belts on eco-climate and consequently on crop yields, etc., in more equable climates.

METEOROLOGICAL RESEARCH COMMITTEE

The 54th meeting of the Committee was held on March 18, 1948.

In order that the Committee may be able to devote more time to considerations of the general policy to be followed in meteorological research it was decided to form three sub-committees, each of which will be responsible for advising on investigations dealing with problems in one part of the research programme and for examining reports on these problems. The three sub-committees correspond to the three parts of the research programme and are as follows:—

Instruments Sub-Committee	Chairman, Prof. P. A. Sheppard
Synoptic and Dynamical Sub-Committee	Chairman, Sir Charles Normand
Physical Sub-Committee	Chairman, Prof. G. M. B. Dobson

Parts I and II of the Research Programme were revised, Part III being left for revision by the Physical Sub-Committee.

The first meeting of the Physical Sub-Committee was held on April 8, 1948.

Part III of the Research Programme was revised.

A report dealing with the variation of mean wind speed in the lowest 350 ft. of the atmosphere was discussed. During this discussion it was agreed that the question of whether the index in the power law, representing the variation of wind with height, can exceed unity is of fundamental importance. The report under consideration was at variance with another unpublished report on this point and the matter was referred back for further examination.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on March 17 at 49 Cromwell Road, Prof. G. M. B. Dobson, President, in the Chair, the following paper was read:—

O. G. Sutton—Convection in the atmosphere near the ground

The earlier theories of turbulence, Prof. Sutton pointed out, regarded the vertical transfer of heat and momentum as being carried on by eddies set up as the wind blows over a rough surface. The vertical velocities in these eddies arise solely from the fluctuations in the horizontal wind. Such a theory fails on clear sunny days of light wind when convection currents are set up over the heated parts of the ground. These upwards currents may be regarded as convectional eddies, composed of upward moving bubbles or streams of heated air which are gradually dissipated by mixing with their surroundings. The intensity of the turbulent convection currents is determined by the balance between the rate of dissipation by breakdown of the heated mass into smaller eddies and the rate of loss of potential energy. Using some results obtained by Taylor, Prof. Sutton shows that the rate of loss of kinetic energy in turbulent motion is proportioned to w'^3/l_H where w' is the upward eddy velocity and l_H is a length determining the scale of the turbulence. Equating this quantity to the rate of loss of potential energy of the rising air we then obtain

$$w' \propto l_H \sqrt{\frac{1}{T}\left(\frac{\delta T}{\delta z} + \Gamma\right)}.$$

The upward moving bubbles of heated air give rise to temperature fluctuations of magnitude T' at any level and Prof. Sutton defines the quantity l_H, which measures the scale of the turbulence, by the equation

$$T' = -\,l_H\left(\frac{\delta T}{\delta z} + \Gamma\right).$$

By analogy with frictional turbulence we also have an eddy coefficient of conductivity K_H equal to $\overline{w'l_H}$.

With these definitions the upward flux of heat is given by

$$q = -\,c_p\rho K_H\left(\frac{\delta T}{\delta z} + \Gamma\right),$$

where c_p, ρ have the usual meanings. If it now be assumed that q is constant with height we can deduce

$$\begin{aligned} w' &\propto l_H^{1/3} \\ \frac{\delta T}{\delta z} + \Gamma &\propto l_H^{-4/3} \\ T' &\propto l_H^{-1/3} \end{aligned}$$

and the problem is reduced to that of finding the relation between l_H and z.

Before considering the variation of l_H with height, however, Prof. Sutton showed that, using the exact equation

$$-\frac{\delta q}{\delta t} = c_p\,\rho\,\frac{\delta T}{\delta t}$$

and values of $\delta T/\delta t$ obtained by Johnson and Heywood at Leafield, the variation of q with height during the midday hours of a fine summer day is so small that it can be neglected, at any rate up to $z = 100$ m., and the assumption that q is a constant is therefore justified.

Turning now to the variation of l_H with height Prof. Sutton used some simultaneous measurements of T' and $\delta T/\delta z$ also obtained at Leafield by Johnson and Heywood. We have seen above that $T'/(\delta T/\delta z + \Gamma)$ is proportional to l_H and by this method Prof. Sutton obtained

$$l_H \propto z^{1\cdot35}$$

and hence

$$K_H \propto z^{1\cdot8}, \qquad \frac{\delta T}{\delta z} + \Gamma \propto z^{-1\cdot8}$$

$$w' \propto z^{0\cdot45}, \qquad T' \propto z^{-0\cdot45}$$

A logarithmic plot of $\partial T/\partial z + \Gamma$ against height showed that $\partial T/\partial z + \Gamma$ varies as $z^{-1\cdot 75}$ in satisfactory agreement with the result deduced above.

Considering next the question of whether buoyancy effects need to be taken into account Sutton pointed out that Elias found the velocity and temperature profiles above a heated plate in a speed of 35 m./sec. in a wind tunnel were practically identical so that in strong winds the transfer of heat and momentum are brought about by the same mechanism. There are no simultaneous observations of wind and temperature profiles in the atmosphere but the usually accepted theory of the variation of wind with height (Schmidt, Ertel, Sutton, Frost) gives a diffusion coefficient of the form z^{1-p}, where p is between 0 and 1, which does not agree with the Leafield observations. Hence, when the temperature lapse rate is steep and wind light, buoyancy must be taken into account.

Finally Prof. Sutton proposed a mathematical model for convective processes in which a thin slab of heated air was supposed to rise under buoyancy forces expanding as it did so. For the details reference must be made to the original paper. Without claiming very exact correspondence with reality Sutton is able to show that the motion of the slab produced a heat flux in close accord with observations.

Mr. Best, opening the discussion on the paper, said he was not satisfied that the flux of heat by radiation could be neglected, as was implicitly done by Sutton, in equating the total flux whose gradient corresponded to the time variation of mean temperature with the flux given by the formula $-K_{H}c_{p}\rho(\partial T/\partial z + \Gamma)$. He confirmed the difficulty of obtaining values of the fluctuations of temperature from recent efforts of his own to read them from the records now being made on a tower at Rye.

Sir Nelson Johnson said that when he was working on these problems the idea that bubbles of heated air produced a heat transfer in addition to that due to mechanical turbulence had always been in his mind. He was very interested to see Sutton's use of his observations. He regretted the Rye records did not show fluctuations.

Mr. Batchelor referred to the fact that the conditions favourable for free convection with rising currents of hot air were also suitable for patterned convection of the Bénard cell type and suggested it would be worth investigating to see if patterned convection did occur. He noted some of the values of l_H were rather larger than the height above ground of the point to which they referred, which agreed with the fact that the temperature fluctuations could only be accounted for by supposing the air producing them to come right up from the hot ground.

Prof. Sheppard doubted whether there really was any difference between the transfer of heat and the transfer of momentum; an eddy transported both impartially.

Dr. Slater said much larger fluctuations than those quoted had been measured under similar conditions by Höhndorf at Darmstadt.

Dr. Robinson considered radiation effects must be taken into account and described work of his own which showed that for the first metre above the soil the radiative flux of heat was almost equal to the convective flux.

Prof. Sutton, replying to the discussion, regretted very much that the Rye tower records gave no information on fluctuations and agreed with Dr. Robinson that radiation needed much more attention.

ROYAL STATISTICAL SOCIETY

At the meeting of the Study Section of the Royal Statistical Society on March 10, a discussion on the use of statistical analysis in meteorology was opened by Miss N. Carruthers. Reference was made to the estimation of normal values, the fitting of theoretical distributions of frequencies* and the effect of persistence in meteorological elements. The persistence effect requires a modification of the well-known expressions for standard error, for these apply only to distributions of independent observations. Two other main topics were correlation and the analysis of periodicities. Among other things, the former had been applied to the investigation of solar and terrestrial relationships and to the seasonal forecasting of weather and crop yields, and the latter had been used to compare meteorological and solar cycles and to review the choice of standard period for normals.

The wide demand for meteorological statistics was emphasised by several " consumers " who, in pointing out their particular needs and their particular lines of investigation, added much to the interest of the discussion. The problem of estimating ground temperatures over a long length of underground cable was raised in connexion with the resistance of telephone cables; weekly forecasts of air temperature for the planning of fuel consumption were the principal need of the Gas Light and Coke Company; and upper air data were required by British European Airways, particularly wind frequencies and forecasts of precipitation static. The Ministry of Health had found growth in height of children to be related to the number of hours of sunshine, and they were now investigating the effects of climate and weather on the incidence and spread of infantile paralysis. The London Transport Board, in connexion with sporting events and Bank Holidays, were concerned with planning for heavy passenger traffic governed largely by weather conditions. In this, a knowledge of the approximate dates of annual recurrence of particular types of weather† had already proved helpful. These instances, of course, form only a small sample of the applications of meteorology but they are sufficient to give some indication of the wide range of problems involved.

N. CARRUTHERS

LETTER TO THE EDITOR

Unusual condensation trails

I was particularly interested in the report by Mr. Aanensen in your January issue on the formation of an unusual condensation trail (a trail forming initially at the propellors).

I am happy to be able to advise Mr. Aanensen that there are some further authenticated occurrences of this phenomenon in existence. Probably the best report is one concerning a flight made at South Farnborough on March 13, 1934, by (I think) the late W./Cdr. (then F./Lt.) Stainforth who was very interested

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*BROOKS, C. E. P.; The numerical basis of climate. *Met. Mag., London*, **76**, 1947, pp. 9, 36, 56.

†BROOKS, C. E. P.; Annual recurrences of weather: " Singularities ", *Weather, London*, **1**, 1946, pp. 107, 130.

in these occurrences and who was a very careful and critical observer of any phenomenon he set out to investigate. He reported " mist streaming from the airscrew at 8,500 ft., sufficiently dense to obscure an object fitted on the top plane." Other reports spoke of " thin flakes of ice-like transparent ' LUX ' coming from the airscrew."

At that time, 1934–5, practically all condensation trails, then referred to as " alto-cumulus formed by aeroplane "* were caused by aircraft flown from R.A.E., Farnborough, who alone flew regularly at the heights where these trails most frequently occur. The aircraft, of course, were all single-engined biplanes, due, as we were destined to discover, for rapid replacement by the monoplane.

In the case quoted the aircraft was a Bulldog with long exhaust pipes trailing back under the fuselage (the exhaust gases were thus precluded from taking any part in the initial formation) and the pilot would be located in the middle of the fuselage, aft of the wings.

Mr. J. S. Smith and myself collected and sifted a goodly quantity of information, relating to these condensation trails, brought in by the pilots and observers at the R.A.E., whose interest in the phenomenon was as great as ours. It was because we had among the comparatively few occurrences some cases in which the trails undoubtedly commenced in circumstances which precluded any possibility of the exhaust gases contributing to the initial formation, that we felt constrained to invoke in our report the pressure reductions caused by the airflow in the immediate vicinity of the fuselage and elsewhere as contributory causes of the formations, as well as to account for the twin character of the trails.

It was also found that trails were formed readily in cloud-free air when there was an occlusion in the vicinity of the British Isles, and also near the boundary of an old cloud system as shown by C. K. M. Douglas in the case reported by Mr. Aanensen.

Unfortunately the trails often occurred at higher levels than those attained by the now famous meteorological flight at Duxford, so not only were we often not able to relate the formation to the tephigram but we certainly had no humidity data for the levels.

F. H. DIGHT

BOOKS RECEIVED

On graduation of data. By Dr. H. J. De Boer. Koninklijk Magnetisch en Meteorologisch Observatorium te Batavia. Verhandelingen No. 33. Size 9¾ in. × 6¼ in. pp. 20. Surabaya, 1947.

WEATHER OF MARCH 1948

Anticyclones influenced the weather over the British Isles during most of the month, which was one of exceptionally high mean pressure. During the first week the centre of highest pressure was to the eastward, but on the 8th and 9th was over France. On the 10th it was to the south-west of Ireland, and from the 11th to the 14th over or near to the British Isles. From the 15th to the 22nd very deep depressions near Iceland brought a spell of southerly to westerly winds over the British Isles, but by the 23rd a new anticyclone had developed

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*See *Met. Mag., London,* **66**, 1931, p. 66; **67**, 1931, p. 89; **72**, 1937, p. 94.

over England. As this system drifted away to Germany there was a spell of fine quiet weather, with winds mainly from between S. and E. changing to a period of very disturbed weather during the last two or three days of the month under the influence of secondary depressions associated with a deep depression near Iceland. There was an exceptionally rapid fall of the barometer on the 31st, and by midnight pressure was down to 954 mb. at Tiree.

The map of mean pressure shows an area with pressure above 1025 mb. covering most of Europe southwards of Scandinavia, and including the western Mediterranean and southern England. Mean pressure was below 1000 mb. between Iceland and Spitsbergen. Pressure was above normal generally over Europe and the Mediterranean, by as much as 15 mb. in south-east England and Holland, and from 10 to 15 mb. below normal in Greenland.

The weather over the British Isles was warm and sunny, it was also dry except over considerable areas in the north-west. Mainly anticyclonic conditions prevailed until the closing days, though troughs of low pressure affected the weather at times, particularly in the north-west. Mean pressure greatly exceeded the average, especially in the south-east; at Oxford the mean for the month was only 0·010 in. below the previous record for March, which occurred in 1929. Considerable fog developed during the first six days and a widespread, severe gale was reported on the 31st.

Mean temperature was exceptionally high; in England and Wales, apart from March 1938, it was the highest for March since before 1901; in Scotland and Ireland there were two higher means, namely 1938 and 1945. It was very warm in England and Wales on the 9th, when temperatures of 70°F. or above were registered at numerous stations. Rainfall exceeded the average over much of the western half of the Scottish mainland, over part of Northern Ireland and locally in Cumberland and Snowdonia. On the other hand less than one quarter of the average was measured in a coastal belt from North Berwick to Morpeth (Northumberland) and from Gordon Castle to the northern tip of Aberdeenshire. Heavy falls of rain occurred in the north-west on the 7th and 20th and, more generally, on the 31st; for example 3·36 in. at Blaenau Festiniog (Merioneth) and 2·58 in. at Ardgour (Argyll) on the 7th, 2·58 in. at Glenquoich (Inverness) on the 20th and 4·28 in. at Thirlmere (Cumberland) and 4·24 in. at Haweswater (Westmoreland) on the 31st.

The duration of bright sunshine was much in excess of the average in England and Wales and exceeded the average in Northern Ireland and, on the whole, in Scotland, though a few places in the latter country received rather less than the average.

The general character of the weather is shown by the following table:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	75	22	+4·7	54	−8	136	44
Scotland	71	20	+4·6	88	−4	114	34
Northern Ireland ..	67	26	+5·5	91	−4	119	35

RAINFALL OF MARCH 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square	·57	31	*Glam.*	Cardiff, Penylan	1·77	56
Kent	Folkestone, Cherry Gdns.	·90	41	*Pemb.*	St. Ann's Head	2·15	79
„	Edenbridge, Falconhurst	·99	40	*Card.*	Aberystwyth	1·22	45
Sussex	Compton, Compton Ho.	1·14	41	*Radnor*	Bir. W. W., Tyrmynydd	3·62	67
„	Worthing, Beach Ho. Pk.	·86	45	*Mont.*	Lake Vyrnwy	4·07	89
Hants.	Ventnor, Roy. Nat. Hos.	·67	33	*Mer.*	Blaenau Festiniog	8·84	102
„	Fordingbridge, Oaklands	1·10	47	*Carn.*	Llandudno	1·39	68
„	Sherborne St. John	1·08	48	*Angl.*	Llanerchymedd	2·15	72
Herts.	Royston, Therfield Rec.	·91	50	*I. Man.*	Douglas, Boro' Cem.	3·01	102
Bucks.	Slough, Upton	·83	47	*Wigtown*	Port William, Monreith	1·39	49
Oxford	Oxford, Radcliffe	·72	44	*Dumf.*	Dumfries, Crichton R.I.	2·79	93
N'hant	Wellingboro', Swanspool	·80	45	„	Eskdalemuir Obsy.	4·53	92
Essex	Shoeburyness	·46	34	*Roxb.*	Kelso, Floors	·78	40
Suffolk	Campsea Ashe, High Ho.	·82	49	*Peebles.*	Stobo Castle	2·69	93
„	Lowestoft Sec. School	·48	30	*Berwick*	Marchmont House	·63	24
„	Bury St. Ed., Westley H.	·76	40	*E. Loth.*	North Berwick Res.	·43	23
Norfolk	Sandringham Ho. Gdns.	·76	40	*Midl'n.*	Edinburgh, Blackf'd. H.	1·06	54
Wilts.	Bishops Cannings	1·11	49	*Lanark*	Hamilton W. W., T'nhill	3·17	114
Dorset	Creech Grange	1·21	43	*Ayr*	Colmonell, Knockdolian	3·63	107
„	Beaminster, East St.	1·52	52	„	Glen Afton, Ayr San.	6·28	150
Devon	Teignmouth, Den Gdns.	1·39	53	*Bute*	Rothesay, Ardencraig	4·19	117
„	Cullompton	1·21	44	*Argyll*	L. Sunart, Glenborrodale	5·41	97
„	Barnstaple, N. Dev. Ath.	1·08	41	„	Poltalloch	4·68	122
„	Okehampton, Uplands	2·72	66	„	Inveraray Castle	9·45	149
Cornwall	Bude School House	1·04	43	„	Islay, Eallabus	4·29	112
„	Penzance, Morrab Gdns.	1·71	53	„	Tiree	3·39	101
„	St. Austell, Trevarna	1·96	57	*Kinross*	Loch Leven Sluice	1·66	56
„	Scilly, Tresco Abbey	1·63	62	*Fife*	Leuchars Airfield	·68	35
Glos.	Cirencester	1·32	57	*Perth*	Loch Dhu	8·43	128
Salop	Church Stretton	1·49	62	„	Crieff, Strathearn Hyd.	2·52	79
„	Cheswardine Hall	·96	45	„	Blair Castle Gardens	2·11	81
Staffs.	Leek, Wall Grange, P.S.	1·19	44	*Angus*	Montrose, Sunnyside	·59	28
Worcs.	Malvern, Free Library	1·18	61	*Aberd.*	Balmoral Castle Gdns.	1·99	70
Warwick	Birmingham, Edgbaston	1·25	65	„	Dyce, Craibstone	·87	33
Leics.	Thornton Reservoir	1·04	57	„	Fyvie Castle	·57	21
Lincs.	Boston, Skirbeck	·50	32	*Moray*	Gordon Castle	·48	21
„	Skegness, Marine Gdns.	·56	34	*Nairn*	Nairn, Achareidh	1·08	59
Notts.	Mansfield, Carr Bank	·65	31	*Inv's*	Loch Ness, Foyers	3·48	108
Ches.	Bidston Observatory	·77	41	„	Glenquoich	12·26	126
Lancs.	Manchester, Whit. Park	·99	44	„	Fort William, Teviot	9·18	137
„	Stonyhurst College	2·63	71	„	Skye, Duntuilm	3·77	86
„	Blackpool	1·61	68	*R. & C.*	Ullapool	2·81	69
Yorks.	Wakefield, Clarence Pk.	·97	54	„	Applecross Gardens	4·90	105
„	Hull, Pearson Park	·61	34	„	Achnashellach	8·53	126
„	Felixkirk, Mt. St. John	1·01	51	„	Stornoway Airfield	3·08	79
„	York Museum	·67	40	*Suth.*	Lairg	2·98	96
„	Scarborough	1·06	59	„	Loch More, Achfary	6·79	105
„	Middlesbrough	·92	59	*Caith.*	Wick Airfield	1·07	47
„	Baldersdale, Hury Res.	2·35	76	*Shet.*	Lerwick Observatory	2·68	85
Nor'ld	Newcastle, Leazes Pk.	·65	32	*Ferm.*	Crom Castle	3·23	104
„	Bellingham, High Green	1·70	58	*Armagh*	Armagh Observatory	2·59	110
„	Lilburn, Tower Gdns.	·79	30	*Down*	Seaforde	2·60	89
Cumb.	Geltsdale	1·65	59	*Antrim*	Aldergrove Airfield	1·47	59
„	Keswick, High Hill	5·14	114	„	Ballymena, Harryville	2·28	72
„	Ravenglass, The Grove	2·97	96	*Lon.*	Garvagh, Moneydig	2·60	83
Mon.	Abergavenny, Larchfield	2·13	70	„	Londonderry, Creggan	3·04	95
Glam.	Ystalyfera, Wern House	5·22	97	*Tyrone*	Omagh, Edenfel	3·64	116

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, NOVEMBER 1947

STATIONS	PRESSURE		TEMPERATURES							REL-ATIVE HUM-IDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
	Mean of day M.S.L.	Diff. from normal	Absolute		Mean values							Total	Diff. from normal	Days	Daily Mean	Per-centage of possible
			Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb							
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1014·0	+0·1	61	23	50·5	40·8	45·7	+1·9	43·6	85	7·5	1·07	—1·15	13	1·9	22
Gibraltar	1019·6	+1·6	78	47	70·3	58·6	64·5	+4·5	60·4	85	4·7	2·09	—	3	—	—
Malta	1015·9	0·0	73	52	69·4	60·2	64·8	+0·9	60·7	68	5·1	0·24	—	4	7·8	76
St. Helena	1015·2	—	67	54	63·8	55·5	59·7	+1·2	55·7	96	9·4	0·74	—0·44	15	—	—
Freetown, Sierra Leone	1010·7	+1·3	88	71	84·9	76·0	80·5	+1·2	75·9	80	5·8	0·75	—4·37	8	6·9	59
Lagos, Nigeria ..	1010·5	+0·4	93	64	89·3	70·4	79·9	—1·8	76·8	83	7·7	1·63	—	5	5·8	49
Kaduna, Nigeria ..	1010·1	—	94	52	89·3	59·2	74·3	—3·6	60·7	30	4·4	0·00	—0·21	0	8·8	76
Chileka, Nyasaland	1012·2	+0·9	96	64	89·8	69·5	79·7	+2·0	68·0	53	4·3	3·04	—0·78	8	7·6	59
Salisbury, Rhodesia..	1010·5	—0·7	92	57	83·3	61·5	72·4	+2·2	61·5	51	4·9	5·19	+1·17	15	7·7	60
Cape Town ..	1014·5	—1·3	88	49	76·1	58·0	67·1	+2·7	60·4	70	4·2	0·22	—0·87	4	—	—
Germiston, South Africa	1010·1	—	92	44	80·8	57·2	69·0	—	58·1	54	4·0	2·88	—	12	9·3	69
Mauritius	1017·4	+1·3	88	62	82·2	65·7	73·9	—1·6	67·1	71	5·0	2·37	+0·61	18	9·0	69
Calcutta, Alipore Obsy.	1014·0	+0·6	92	59	87·3	64·6	75·9	+2·4	66·4	86	1·1	0·00	—0·65	0	9·2	83
Bombay	1012·9	+0·9	93	69	88·6	72·9	80·7	+0·1	72·0	80	2·2	0·00	—0·45	0	9·9	89
Madras	1013·0	+1·7	93	67	86·2	71·1	78·7	—0·2	72·1	81	4·3	2·81	—10·80	6	8·6	75
Colombo, Ceylon ..	1011·8	+1·8	90	66	87·2	71·7	79·5	—0·5	72·9	86	4·0	5·72	—6·04	7	9·3	79
Singapore	1010·1	+0·7	89	70	85·8	73·4	79·6	—1·0	76·9	85	—	8·80	—1·11	20	—	—
Hongkong	1016·8	—0·8	84	54	76·5	65·5	71·0	+1·4	64·0	69	—	0·56	—1·18	10	6·1	55
Sydney, N.S.W. ..	—	—	86	52	70·5	58·0	64·3	—2·7	58·9	65	7·1	3·31	+0·46	14	7·0	50
Melbourne	1012·8	—1·6	90	43	68·2	50·1	59·1	—2·2	53·3	61	7·5	2·02	—0·21	15	5·7	40
Adelaide	1014·1	—1·2	98	43	73·2	53·1	63·1	—3·9	55·5	54	5·5	1·18	+0·04	10	7·7	55
Perth, W. Australia	1014·9	—0·5	93	45	75·5	55·6	65·5	—0·6	58·7	58	3·1	0·49	—0·31	5	10·1	73
Coolgardie	1014·4	+1·0	96	41	81·7	54·4	68·1	—2·6	55·0	46	3·4	0·87	+0·28	4	—	—
Brisbane	1012·9	—1·7	90	57	78·6	63·2	70·9	—2·6	63·7	65	6·6	2·80	—0·93	12	7·3	57
Hobart, Tasmania ..	1012·3	+2·7	88	40	63·6	46·7	55·1	—2·1	49·8	60	8·2	1·37	—1·10	19	7·0	48
Wellington, N.Z. ..	1018·4	+6·3	74	38	63·1	49·8	56·5	+0·9	53·4	67	6·9	1·05	—2·47	7	8·5	59
Suva, Fiji	1010·3	—0·8	89	69	82·1	72·1	77·1	0·0	71·7	77	7·5	4·90	—4·89	16	6·0	47
Apia, Samoa ..	1009·2	—0·3	89	73	85·8	73·9	79·9	+1·2	77·1	79	6·6	12·92	+3·09	23	7·1	56
Kingston, Jamaica ..	1012·8	+0·4	93	71	90·1	73·3	81·7	+2·4	74·8	75	2·8	0·49	—2·54	2	9·4	83
Grenada, W. Indies	1010·5	—0·1	88	65	86·8	73·9	80·3	+0·8	76·3	76	5·0	2·43	—6·03	14	—	—
Toronto	1017·1	—0·2	58	19	43·5	32·8	38·1	+1·1	33·0	—	7·3	1·29	—1·34	7	3·6	37
Winnipeg	1015·8	—1·6	55	13	26·5	13·2	19·9	—1·4	16·9	—	6·7	0·91	—0·16	15	3·0	33
St. John, N.B. ..	1014·2	—0·4	60	18	44·4	31·7	38·1	+1·4	33·1	—	6·8	3·85	—0·56	15	3·4	35
Victoria, B.C. ..	1020·7	+4·8	57	26	48·2	36·0	42·1	—2·4	38·4	98	6·8	2·45	—2·96	16	3·3	35

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SOME ASPECTS OF THE THEORY OF TURBULENCE

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Part III

Up to now we have confined our ideas to a fairly realistic picture of atmospheric motion, and have tried to define our concepts in relation to it. Sooner or later, however, theoretical results have to be compared with actual measurements, and it is necessary to put one's theories in a form suited to such a comparison. This often entails drastic assumptions and incomplete formulations, and the precise physical significance of the steps involved is almost invariably lost sight of. But the experience is normally a salutary one provided the assumptions made are clearly stated. The remainder of this article gives a brief outline of a few past attempts at conjoining theory with practice. It follows on from the fundamental equation $\partial\bar{\theta}/\partial t = -\partial(\overline{w'\theta'})/\partial z$, deduced in Part I, and deals with its resolution in terms of mixing-length concepts. The first few paragraphs are by way of a digression in order to provide us with sufficient background to understand current terminology and to appreciate subsequent advances.

The presiding genius in the dynamical theory of turbulence is Osborne Reynolds, who laid the foundation of modern developments in a classical paper published in 1894.[1*] He considered the terms to be introduced into the equations of mean motion in order to allow for the presence of the eddy velocities (defined earlier), and in view of their importance it would be as well to give them in full.[†] The equations of mean motion on the earth's surface are:—

$$\rho\frac{D\bar{u}}{Dt}+2\rho\omega(\bar{w}\cos\phi-\bar{v}\sin\phi)=-\frac{\partial\bar{p}}{\partial x}-\frac{\partial}{\partial x}(\rho\overline{u'u'})-\frac{\partial}{\partial y}(\rho\overline{u'v'})-\frac{\partial}{\partial z}(\rho\overline{u'w'})+\mu\nabla^2\bar{u} \quad (7)$$

$$\rho\frac{D\bar{v}}{Dt}+2\rho\omega\bar{u}\sin\phi=-\frac{\partial\bar{p}}{\partial y}-\frac{\partial}{\partial x}(\rho\overline{v'u'})-\frac{\partial}{\partial y}(\rho\overline{v'v'})-\frac{\partial}{\partial z}(\rho\overline{v'w'})+\mu\nabla^2\bar{v} \quad (8)$$

$$\rho\frac{D\bar{w}}{Dt}-2\rho\omega\bar{u}\cos\phi=-\rho g-\frac{\partial\bar{p}}{\partial z}-\frac{\partial}{\partial x}(\rho\overline{w'u'})-\frac{\partial}{\partial y}(\rho\overline{w'v'})-\frac{\partial}{\partial z}(\rho\overline{w'w'})+\mu\nabla^2\bar{w} \quad (9)$$

in which $\bar{u}$, $\bar{v}$, $\bar{w}$ are the components of mean velocity along mutually perpendicular coordinate axes OX, OY, OZ (drawn horizontally to the east, horizontally to the north, and vertically, respectively), u', v', w' are the corresponding eddy velocities, p the atmosphere pressure, ρ the air density, ω the angular velocity of rotation of the earth about its axis, ϕ the latitude, and μ the coefficient of molecular viscosity of air. The symbol D/Dt represents differentiation following the mean motion and ∇^2 is the normal Laplacian operator. Thus we have the following identities:—

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* These numbers refer to the list of references on p. 128.

† For the derivation of equations (7)–(9) see Brunt's " Physical and dynamical meteorology ".

$$\frac{D}{Dt} \equiv \frac{\partial}{\partial t} + \bar{u}\frac{\partial}{\partial x} + \bar{v}\frac{\partial}{\partial y} + \bar{w}\frac{\partial}{\partial z}$$

$$\text{and} \qquad \nabla^2 \equiv \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}.$$

The terms involving ω and ϕ are the familiar Coriolis forces due to the earth's rotation. By analogy with the molecular shear stresses $\mu\partial\bar{u}/\partial x$, $\mu\partial\bar{v}/\partial y$, etc., the characteristic parameters $-\rho\overline{u'u'}$, $-\rho\overline{u'v'}$, etc., were called "eddy" shear stresses, and are often written τ_{xx}, τ_{xy}, etc. In these equations a bar over a particular symbol implies a mean value with respect to time. They only apply to an incompressible fluid, and may be simplified further by neglecting molecular viscosity by comparison with eddy viscosity. Assuming also that there is no mean vertical velocity ($\bar{w} = 0$) and ignoring all horizontal gradients (i.e. all terms involving the operators $\partial/\partial x$ and $\partial/\partial y$) except those of pressure, the equations reduce to

$$\frac{\partial u}{\partial t} - 2\,\omega\,\bar{v}\sin\phi = -\frac{1}{\rho}\frac{\partial\bar{p}}{\partial x} + \frac{1}{\rho}\frac{\partial\tau_{xz}}{\partial z} \qquad \ldots (10)$$

$$\frac{\partial v}{\partial t} + 2\,\omega\,\bar{u}\sin\phi = -\frac{1}{\rho}\frac{\partial\bar{p}}{\partial y} + \frac{1}{\rho}\frac{\partial\tau_{yz}}{\partial z} \qquad \ldots (11)$$

$$-\,2\,\omega\,\bar{u}\cos\phi = -\,g - \frac{1}{\rho}\frac{\partial\bar{p}}{\partial z} + \frac{1}{\rho}\frac{\partial\tau_{zz}}{\partial z} \qquad \ldots (12)$$

If U, V are the horizontal components of the geostrophic wind, neglecting vertical variation of the horizontal pressure gradient within the friction layer,

$$\text{then} \qquad 2\,\omega\,V\sin\phi = \frac{1}{\rho}\frac{\partial\bar{p}}{\partial x}$$

$$\text{and} \qquad -\,2\,\omega\,U\sin\phi = \frac{1}{\rho}\frac{\partial\bar{p}}{\partial y}$$

and substituting in equations (10) and (11) we obtain

$$\frac{\partial\bar{u}}{\partial t} + 2\,\omega\,(V - \bar{v})\sin\phi = \frac{1}{\rho}\frac{\partial\tau_{xz}}{\partial z} \qquad \ldots (13)$$

$$\frac{\partial\bar{v}}{\partial t} - 2\,\omega\,(U - \bar{u})\sin\phi = \frac{1}{\rho}\frac{\partial\tau_{yz}}{\partial z} \qquad \ldots (14)$$

It will be noticed that if we ignore the change of wind with height in the lowest layers of air, and take our x-axis parallel to the direction of the mean wind (i.e. $\bar{v} = V = 0$), equation (13) becomes

$$\frac{\partial\bar{u}}{\partial t} = \frac{\partial\tau_{xz}}{\partial z} = -\frac{\partial}{\partial z}(\overline{u'w'}), \qquad \ldots (15)$$

which is the two-dimensional equation previously arrived at in Part I for momentum transfer, making the same assumptions. A more accurate expression can be got from (10); by re-orientating the axes as before ($\bar{v} = 0$), we have

$$\rho\frac{\partial \bar{u}}{\partial t} = -\frac{\partial \bar{p}}{\partial x} + \frac{\partial \tau_{xz}}{\partial z} \qquad .. (16)$$

which includes the pressure gradient along the direction of the mean motion at a particular level, and it is a moot point as to whether or not this term may invariably be neglected by comparison with the others. Strictly speaking equation (15) only represents the changes in the mean velocity due to the eddy stresses. Insofar as the horizontal pressure gradient is more or less constant in the lowest few metres of the atmosphere, and since there is usually no observable wind-direction change with height, the effect of the factor is to accelerate the air bodily, whereas the last term in equation (16) produces differences of velocity with height. We are thus enabled to separate the two in practice by dealing with differences of velocity from a standard height rather than absolute values.

The above equations will be referred to again later; meanwhile one example of terminology is of interest. Consider the parameter $-\rho\overline{u'w'}$; since it is of the nature of a shear stress, we may write

$$-\rho\,\overline{u'w'} = \tau_{xz} = \rho K\frac{\partial \bar{u}}{\partial z} \qquad .. (17)$$

by analogy with molecular viscosity in laminar flow, where K is called the coefficient of eddy viscosity.

Practical application.—The idea of mixing length was first introduced by Taylor in England, and independently by Prandtl in Germany, although it was the latter who built a consistent theory around it. He was concerned only with momentum transfer and, in this case, the problem is to find a way of expressing $-\rho\overline{u'w'}$ in terms of measurable quantities. As we have seen $u' = l_1\partial\bar{u}/\partial z$, l_1 being the so-called *Mischungsweg* or mixing length, and assuming w' to be of the same form, $\pm l_2\partial\bar{u}/\partial z$, say, the eddy shearing stress may be written

$$\tau = -\rho\,\overline{u'w'} = \pm\,\rho\, l_1\, l_2\left(\frac{\partial \bar{u}}{\partial z}\right)^2 = \pm\,\rho\, l^2\left(\frac{\partial \bar{u}}{\partial z}\right)^2,$$

where $l^2 = l_1\, l_2$. If the mean velocity increases with height it is obvious that when w' is positive u' must be negative and *vice versa* so that to have the correct sign the above equation becomes

$$\tau = \rho\, l^2\left|\frac{\partial \bar{u}}{\partial z}\right|\frac{\partial \bar{u}}{\partial z}, \qquad .. (18)$$

where $|\partial\bar{u}/\partial z|$ is the absolute value of the mean gradient. From (17), substituting for τ (the suffixes are dropped for convenience) we have

$$K = l^2\left|\frac{\partial \bar{u}}{\partial z}\right|. \qquad .. (19)$$

These two equations are the principle links in the theory; l is now simply a quantity with the dimensions of a length and only roughly corresponds to previous specifications. The next step is to determine the dependence of l on other factors. Von Kármán[2], on the hypothesis that turbulence, apart from scale, is geometrically similar throughout the field of flow (the principle of dynamical similarity) deduced that

$$l = k_0 \left| \frac{\partial \bar{u}}{\partial z} \right| \Big/ \left| \frac{\partial^2 \bar{u}}{\partial z^2} \right|, \quad \text{.. (20)}$$

where k_0 is a dimensional constant. Its value was first measured by Nikuradse[3], in 1932, for the flow of water in cylindrical pipes, and was found to be about 0·4; it is apparently a universal parameter and does not depend on the Reynolds' number. Now it is by no means certain that the l in this equation is the same as that of the previous two; in fact it should be a very good representation of the transport length l of Part II, which depends entirely on the dynamics of the eddies, whereas that of equations (17) and (19) is more akin to the earlier ideas of mixing length, which we have called l_0. However, if we do assume l to be the same in all three equations and if, in addition, it is assumed that the eddy shearing stress is constant and equal to τ_0 (its value at the boundary), we may eliminate l from equations (18) and (20), and obtain the solution

$$\bar{u} = \frac{1}{k_0} \sqrt{\left(\frac{\tau_0}{\rho}\right)} \cdot \log \frac{z + z_0}{z_0}, \quad \text{.. (21)}$$

as the law of variation of $\bar{u}$ with height, where z_0 is a constant of integration. This equation only holds for flow near to an aerodynamically rough surface, that is one above which turbulence is fully developed right down to it, and for which there is no slip at the boundary ($\bar{u} = 0$ when $z = 0$). The formula when substituted in (20) gives

$$l = k_0(z + z_0) \quad \text{.. (22)}$$

All the above equations were first applied to laboratory experiments, for flow in tubes and wind tunnels, etc., and here z_0 is a roughness parameter. An equation of the form of (21) was shown to describe the velocity profile in a wide variety of circumstances in spite of the fact that the shear stress was known to vary with distance from the boundary, which led Thorade[4] to suggest that the variations in τ are possibly compensated by variations in l.

Because of the generality of the above concepts it was an easy step to attempt to apply them to the atmosphere, even in cases of wide departure from the isothermal conditions of the laboratory, and it is a remarkable fact that they do accord with our experience. Except in the cases of a plane sheet of water or a smooth expanse of ice with light winds, the earth's surface is always aerodynamically rough and equation (21) should apply provided τ is constant with height. Sutton[5], among others, has shown that a logarithmic law is a good approximation to wind profiles, measured under all conditions of thermal stability, in the lowest two metres of the atmosphere. His equation is of the form

$$\frac{\bar{u}}{\bar{u}_1} = \frac{\log(\alpha z/z_1 + 1)}{\log(\alpha + 1)} \quad \text{.. (23)}$$

where $\bar{u}_1$ is the mean wind at a standard height, and α is a turbulence parameter which increases enormously with instability and depends to a less extent on the surface roughness. This formula is, of course, another form of equation (21), for which $z_1 = \alpha z_0$, so that z_0 is a function both of lapse rate and surface roughness. In the laboratory z_0 is a physical constant directly proportional to the average height of the surface-roughness elements, but in the atmosphere, because the dependence of α on lapse rate, this is not so, and Sutton suggested that the surface roughness is much more influential in inversions (when α is small) than under unstable conditions. Sverdrup[6], however, while not refuting the idea, has taken the view that z_0 is an absolute constant for a particular surface, and showed that a better fit, in the unstable state at least, to Sutton's data could be obtained by slightly modifying the logarithmic formula by the addition of a term βz, where β replaces the turbulence parameter α. In inversions Sverdrup's equation is not so good. On the available evidence it is impossible to decide between the two formulæ especially as the fact of the constancy of eddy shear with height, on which they are based, may be disputed except in the steady state. Ertel[7], using equations (13) and (14) with $\partial\bar{u}/\partial t$ and $\partial\bar{v}/\partial t$ both equal to zero, showed that in this case one may ignore the variations of τ with height, at least in the lowest 30 m. of the atmosphere. His proof assumed that there is no change of wind direction with height over this range, and was for isotropic turbulence only. Calder[8] remedied the first defect and demonstrated that the small variations actually observed over this range had very little effect on Ertel's result. He also showed that, although the change of wind direction in the lower atmosphere is of no measurable significance (presumably for steady winds) a very small variation (of the order of 1°/100 m.) suffices to account for a large vertical velocity gradient. This work, of course, constitutes a justification for the use of the approximate equation (15) in the steady state, because here $\partial\bar{u}/\partial t$ and $\partial\tau/\partial z$ become zero together so that τ is necessarily constant with height.

Sheppard[9] actually measured the drag τ_0 of the wind on a concrete surface flush with the ground and, using equation (21), established that 0·4 was a reasonable value for k_0 in the atmosphere under isothermal conditions. He deduced from his own and Best's observations[10] that k_0 decreases with increasing stability, but the reality of these variations is by no means universally accepted, and the author himself remarked that the validity of the results depended on that of the equations used in their computation, and that Kármán's constant must be used with care in the lower atmosphere even when a value adjusted for stability is employed. Although a logarithmic profile is a good approximation to the mean-wind profile in the lowest 1–2 m., power laws are probably better in inversions over a much greater depth and are a good approximation in all stabilities for $z > 1$ m. Whichever law really applies, equation (18), in the form

$$l = \sqrt{\left(\frac{\tau_0}{\rho}\right)} \Bigg/ \left|\frac{\partial\bar{u}}{\partial z}\right| ,$$

may be used to calculate the variation of mixing length with height. Sheppard's results suggested a linear relation for heights up to 1 m., but above that l increased more rapidly than the height for an unstable atmosphere, and probably less rapidly in inversions, as might have been expected. This statement, it must be emphasised, depends on the assumption that $\tau = \tau_0$ at all heights and under all circumstances, for which there is little factual evidence. The remarks about the variation of K_θ with height and stability in Part II are based on a similar hypothesis.

To utilise these equations for the diffusion of other properties—they were originally deduced for momentum transfer only—it is usual to equate the three coefficients of eddy viscosity, eddy conductivity and eddy diffusivity. As we have seen there is good reason to doubt that their absolute magnitudes are equal, but there is some evidence that as far as their law of variation with height is concerned they are similar in form near the ground. The most important general theory, and one which makes this assumption, is perhaps that of O. G. Sutton[11] previously referred to. By a most ingenious combination of empiricism, statistics and mixing-length ideas, he extended the theory given in Part I as far as equation (1), and arrived at the partial-differential equation:

$$\frac{\partial\bar{\theta}}{\partial t} = \alpha_1 \frac{\partial}{\partial z}\left(z^{1-m}\frac{\partial\bar{\theta}}{\partial z}\right) \qquad .. (24)$$

where θ is any property as before, and m, for meteorological purposes, is a function of the vertical temperature gradient and the roughness of the surface ($0 \leqslant m \leqslant 1$) while α_1 is a function of m and the kinematic viscosity of air. The dependance of eddy diffusion on molecular mixing is thus explicitly recognised. The equation is more often given in the form

$$z^m \frac{\partial\chi}{\partial x} = \alpha_2 \frac{\partial}{\partial z}\left(z^{1-m}\frac{\partial\chi}{\partial z}\right) \qquad .. (25)$$

Where χ stands for the excess of a particular property acquired in moving a horizontal distance x, disregarding the original distribution of θ and its subsequent redistribution. It is soluble under practically any boundary conditions provided m is constant, and the theory has been tested in the laboratory for the turbulent transfer of momentum, heat and vapour above aerodynamically smooth surfaces (to which it strictly applies) with excellent results—see Pasquill[12] and others. It can only be applied to the atmosphere under conditions for which m is constant with time, that is, when the lapse rate of temperature is not varying or when the wind is strong. For the problem of the diurnal variation of various properties, m is a function of t, the time, not necessarily a simple one, and the mathematical difficulties of solution become prohibitive.

Sutton's formula leads to power laws for the profiles and diffusivities of the various properties in the steady state, and a linear law for the distribution of the mixing length with height. Frost[13], on the hypothesis that

$$l = z^{1-m} z_0^{\,m}, \qquad .. (26)$$

where z_0 is a length characterizing the degree of roughness of the surface, arrived at an equation identical in form to Sutton's, but the resemblance between the two theories is only superficial. In the first place Sutton did not use equations (18) and (19) from which Frost started. Secondly, substituting this expression for the mixing length in equation (19), we easily get

$$\bar{u} = \frac{1}{m}\sqrt{\left(\frac{\tau_0}{\rho}\right)} \cdot \left(\frac{z}{z_0}\right)^m,$$

which is a power law, and if we accept von Kármán's principle of dynamical similarity, as Sutton did, the value for $\bar{u}$ when substituted in (20) gives $l = k_0 z/(m - 1)$, which is inconsistent with (26). Frost dealt with the evaporation from a plane water surface and gave a very elegant mathematical solution of equation (25) for the relatively simple boundary conditions that obtain in this case. His results when applied to the average drift of air over the Atlantic Ocean and later over the British Isles, were in remarkable agreement with observations. He assumed, among other things, that initially the distribution of moisture in the vertical was constant, and that there is no mean evaporation from a land surface. The former is unlikely and the latter is nothing like true except in winter (see Sumner[14]). Because of these limitations the paper cannot be regarded as rigorously confirming Sutton's theory under atmospheric conditions.

Sutton, himself, has recently produced a paper[15] describing experiments on the diffusion of gases and smokes in the atmosphere under conditions of small temperature gradients, carried out several years ago at the Chemical Defence Experimental Station, Porton. There were, however, considerable discrepancies between the unmodified theory and practice, all of which could be attributed to the fact that the earth's surface is not usually aerodynamically smooth. More recent (unpublished) work at Porton, under Mr. K. L. Calder, seems to indicate that atmospheric diffusion can be very satisfactorily predicted provided surface roughness is taken into account. Although the approach is different, the evaporation formulæ derived are identical with Sutton's in the particular case of a smooth surface, while those obtained for rough surfaces are in excellent agreement with observations on the diffusion of smoke and vapour in the lower atmosphere under adiabatic conditions. These results are very encouraging and, it is to be hoped that a complete account of them will soon be published.

Retrospect and prospect.—There have been several omissions in this essay without which a really comprehensive survey of the subject is impossible. Among them are the writings of Rossby and Montgomery in America, and the work of G. I. Taylor on diffusion by continuous movements in England. Taylor's theory is one of the most remarkable in the entire field; it is still growing and may, in the long run, throw light on many practical problems. Even a complete treatise on turbulence, however, would show significant gaps in our knowledge. Little is known, for example, about the correlation between the eddy velocities of the same fluid element at different times or between the various diffusible properties, or the origin of turbulence. Does turbulence start at the boundaries, and " diffuse " upwards, like vorticity in an incompressible viscous fluid, or can it appear spontaneously in the free atmosphere ? The answer to this, and many other questions, lies in the future. The greatest difficulties arise in that part of the atmosphere immediately above the earth's surface; fortunately it is the easiest to explore, and in this connexion, much experimental work has been done, but much remains to be done. What strikes one most about the subject, is the amazing web of simplifying assumptions that has been spun, requiring a very nimble and highly mathematical spider safely to negotiate it. Several of its strands are wearing thin; most of them need a periodic redusting. Looking back it cannot be said that we have yet mastered the intricacies of fluid flow in a turbulent medium. The motion itself defies the imagination, and creation of the necessary working concepts defies the intellect. One may conjecture, however, that future progress, if it follows traditional lines, will be towards a greater complexity, in which it will be necessary to take account, in a suitable mathematical form, of the fluctuations of the transferable property in question, the eddy velocity (the mechanism) and possibly the atmospheric pressure as well (the driving agency). The further development of micro-instruments to measure atmospheric fluctuations will undoubtedly be of primary importance in research.

But there is another alternative to the slow painstaking development of existing ideas and analysis of observational data, although it is one that is perhaps very remote. Taking a broader view, it is evident that the fundamental difficulties are common to science in general. The greatest obstacle seems to be the impossibility of forming an adequate concept of process. This partly arises because of an over-emphasis on the purely quantitative aspects of phenomena, which has been a necessary, and very profitable, preoccupation of scientists for centuries. Science, however, has never been able completely to disregard the qualitative, and it is widely felt nowadays that the old dualism of quantity and quality is breaking down. What will ultimately emerge it is impossible to say—one can seldom see far beyond the horizon—but it may be of radical importance to all branches of meteorology.

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A NOTE ON THE DEPRESSION OF JANUARY 9–10, 1948

BY E. J. PERCIVAL, B.A.

On January 9–10, 1948, a small depression moved on an approximately easterly track from south-west of Ireland in the early morning of the 9th to near Warsaw on the afternoon of the 10th. Certain features of the movement and the variations of intensity of this depression appeared worth investigating.

History of the depression.—Figs. 1–4 illustrate the movement of the depression and the changes in its central pressure. At 0300 G.M.T. on the 9th the centre was south-west of Ireland at about 51°N. 13°W. In the next

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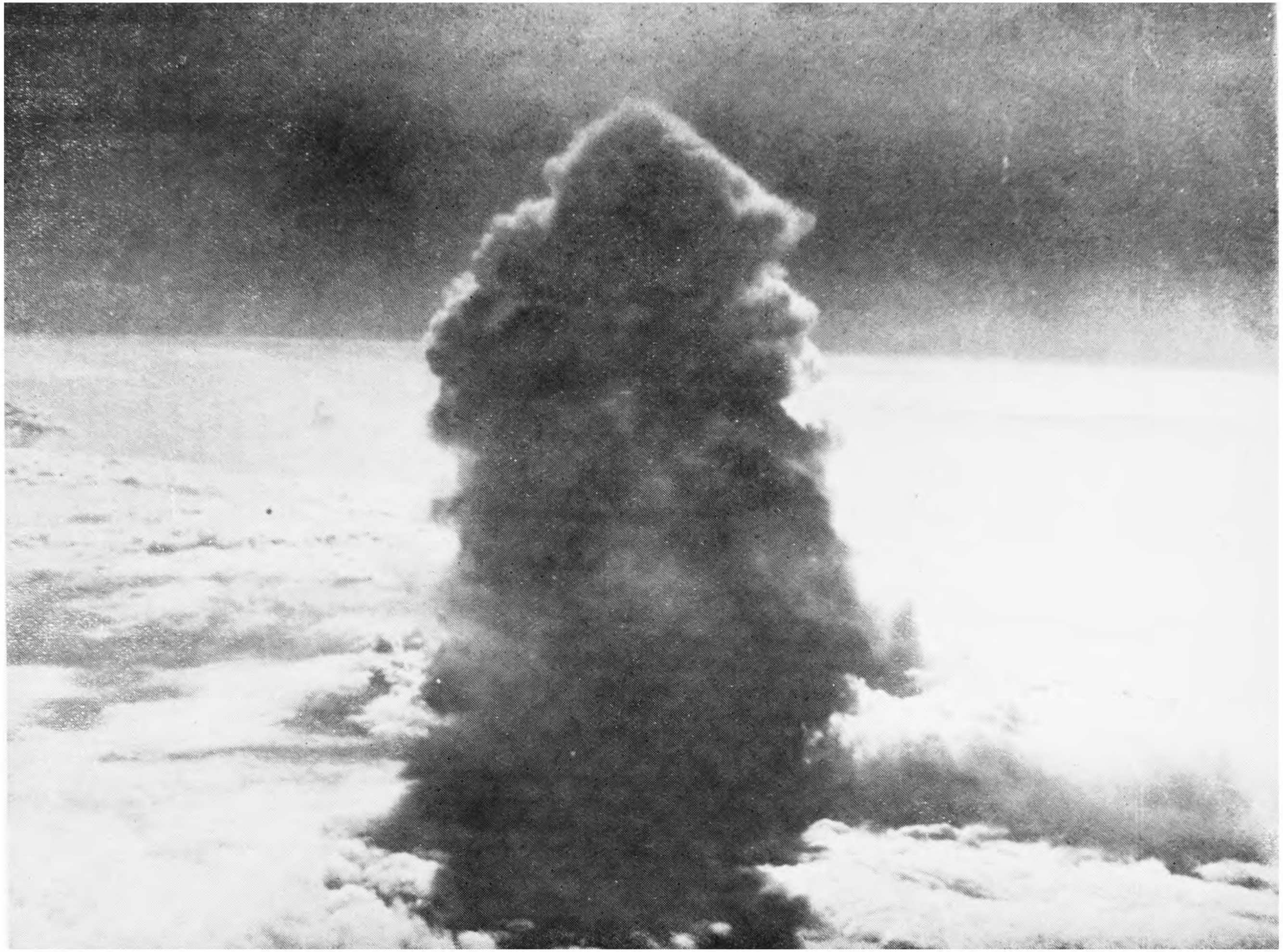

Photograph by R.A.F

CUMULONIMBUS CLOUD AT OLDENBURG, 1745, JULY 27, 1944

Base of the cumulonimbus at 4,000 ft., top at 31,000 ft. Top of stratocumulus layer at 9,000 ft.

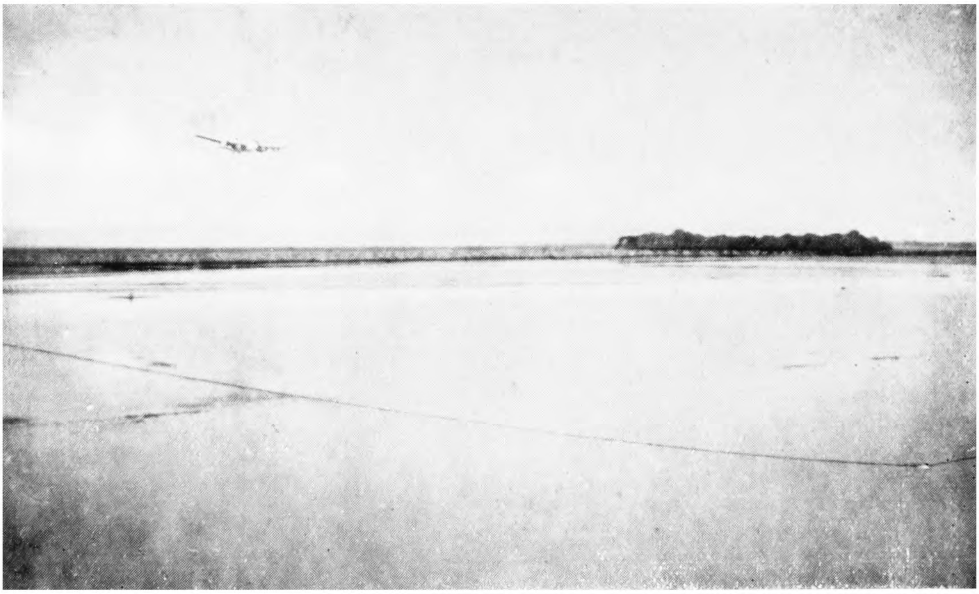

FIG. 3—LOOKING NORTH FROM THE CONTROL TOWER

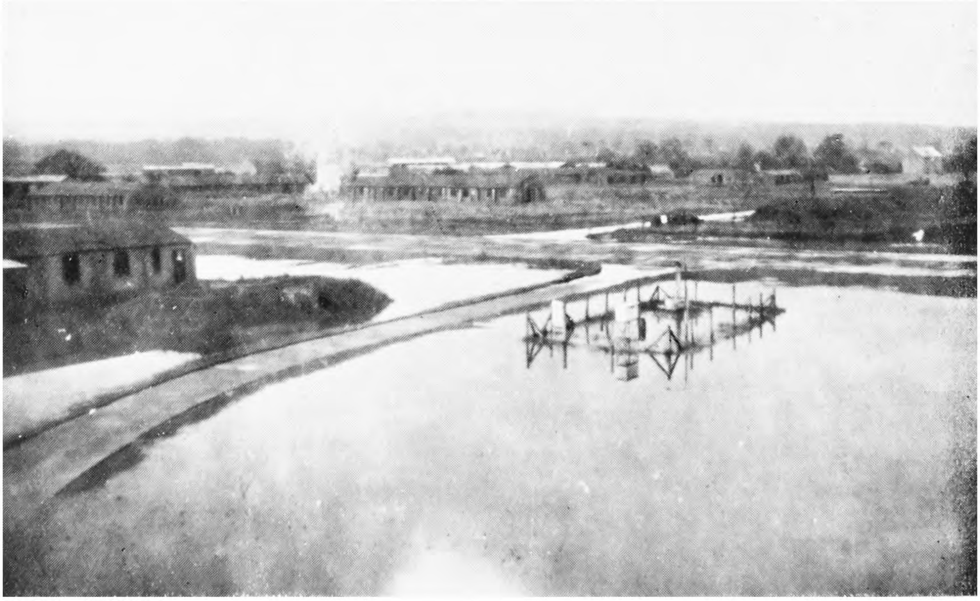

FIG. 4—LOOKING SOUTH TOWARDS THE ENCLOSURE

FLOODS AT BALLYKELLY, NORTHERN IRELAND

These photographs were taken on July 30, 1947, two days after the flooding, when it had subsided a little.

six hours it moved a little south of east* to about 50½°N. 9°W. at 0900, and then on a more north-easterly track to 51½°N. 5°W. at 1500 and 53°N. 1°W. at 2100. It then turned to the right and accelerated, reaching 52½°N. 4½°E. by 0300 on the 10th (giving heavy gales in Holland and the Rhineland), and then moved quickly eastward to 52½°N. 10°E. at 0900 and 53°N. 17½°E. at 1500.

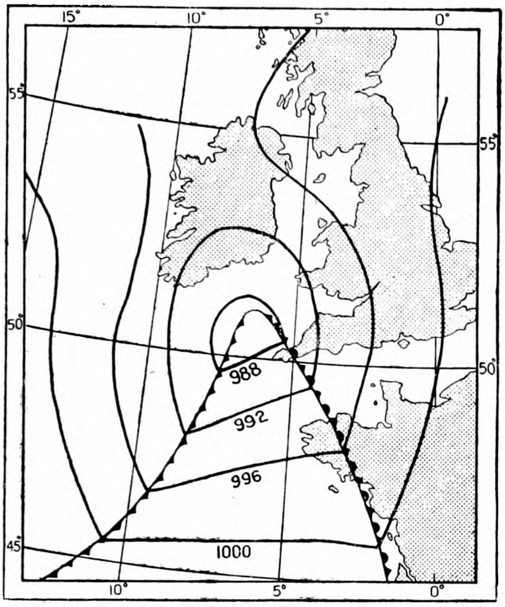
15°
10°
5°
0°
55°
50°
45°
988
992
996
1000

FIG. 1—1200 G.M.T., JAN. 9, 1948

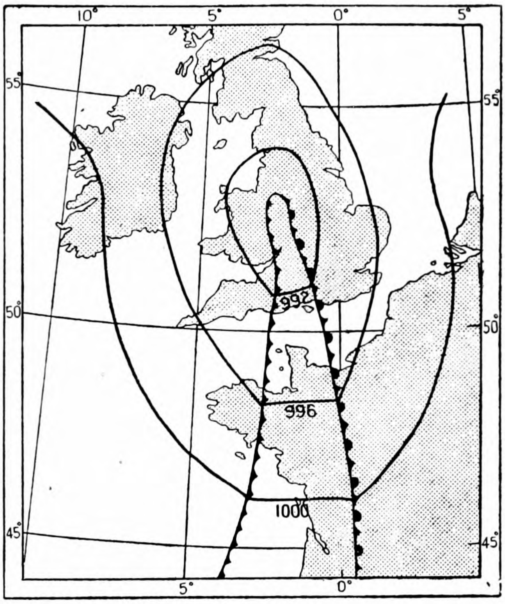
10°
5°
0°
55°
50°
45°
992
996
1000

FIG. 2—1800 G.M.T., JAN. 9, 1948

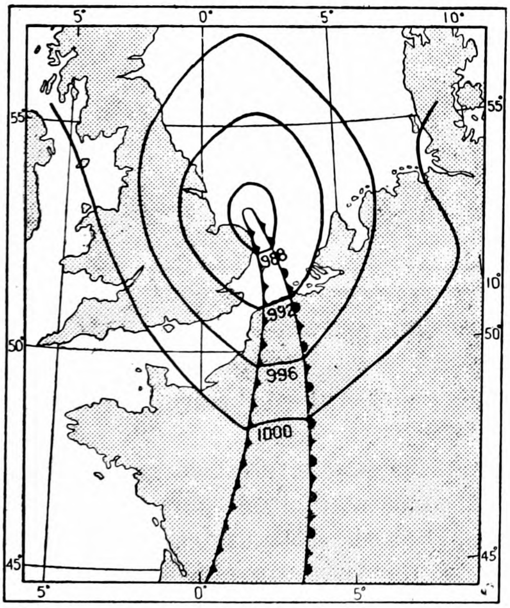
5°
0°
10°
55°
50°
45°
988
992
996
1000

FIG. 3—0000 G.M.T., JAN. 10, 1948

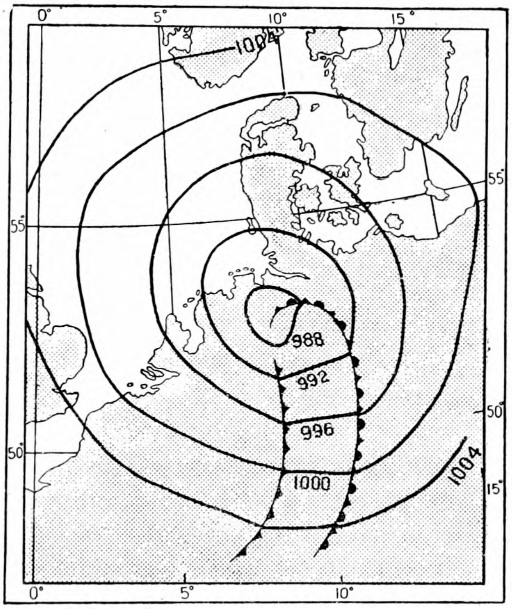
0°
5°
10°
15°
55°
50°
1004
988
992
996
1000
1004

FIG. 4—0600 G.M.T., JAN. 10, 1948

The depth showed little change at 986 mb. for the first six hours, and then filled a little to 988 or 989 mb. at 2100. During the next six hours there was a rapid deepening, to 984 mb. at 0300 on the 10th, followed by a steady filling up to 991 mb. at 1500. At 0300 on the 9th, the depression appears on the chart as a secondary at the tip of a narrow warm sector, but during the next few hours this sector occluded rapidly, so that, by 0900, the depression had only a very weak "false" warm sector between the two parts of the occlusion. Later the backbent occlusion developed cold-front characteristics, and it may have been that the introduction of a new supply of cold air from the north led to some regeneration of the depression. However, the frontal analysis seems to give a very inadequate picture of what happened. An analysis is attempted of regarding the depression as essentially a non-frontal closed circulation below wave-shaped upper isobars, with the horizontal convergence or divergence aloft in the neighbourhood of the centre as the important factor.

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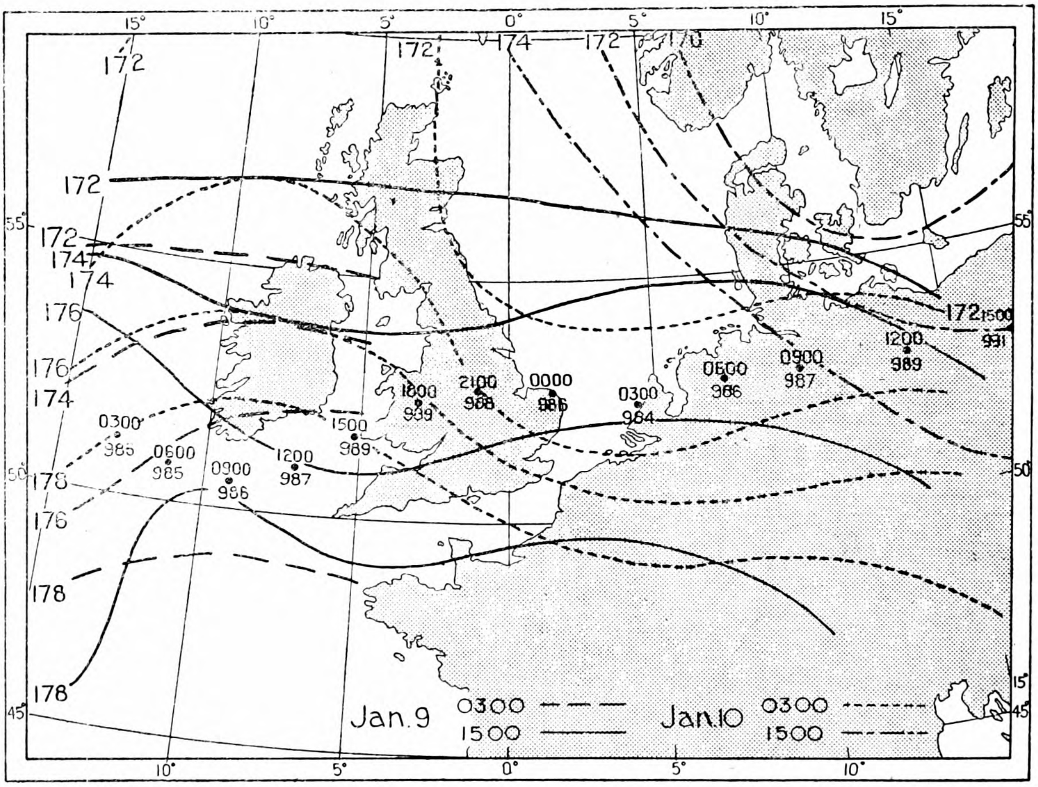
*This is doubtful, as the position of the centre at 0300 is somewhat doubtful, and may have been a little further to the south.



15°
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1200 989
0900 987
0600 986
0300 984
0000 986
2100 988
1800 989
1500 989
1200 987
0900 986
0600 985
0300 985
55
50
45
15
Jan. 9 0300 — — —
1500 ———
Jan. 10 0300 - - - - - -
1500 — - — - —
10°
5°
0°
5°
10°

FIG. 5—ABSOLUTE TOPOGRAPHY OF THE 500-MB. SURFACE AT 0300 AND 1500 ON JANUARY 9, 1948, AND 0300 AND 1500 ON JANUARY 10, 1948

Contours are at 200-ft. intervals. Positions of the centre of the depression at 3-hourly intervals are also indicated.

Upper air structure.—The absolute contours at 500 mb. (see Fig. 5) show a well marked trough, which moved rapidly eastward, from about 20°W. at 0300 on the 9th to 5°W. at 1500, 5°E. at 0300 on the 10th and 16°E. at 1500. Until 1500 on the 9th it was quite shallow; at this time it overtook the surface depression and became rapidly deeper. The height of the 500-mb. surface at the centre of the depression fell from about 17,500 ft. at 0300 and 1500 on the 9th to 17,300 ft. at 0300 and 17,200 ft. at 1500 on the 10th. The corresponding thicknesses (Fig. 6) of the 1000–500 mb. layer were 17,800 ft., 17,800 ft., 17,600 ft. and 17,250 ft. respectively. Thus, during the latter part of its history while the surface depression was moving approximately with the upper trough, the air in its neighbourhood in the lower half of the atmosphere got steadily colder.

Movement of the upper trough.—Certain features of the movement of long waves in the atmosphere have been discussed by J. Bjerknes and J. Holmboe*. The quantitative results theoretically derived by these authors are not properly applicable in the present case, as the departure is too great from the idealised wave form they consider; in particular, their fundamental assumption is violated, that the whole wave from wedge to wedge is situated symmetrically with respect to the trough. However, from a qualitative viewpoint their results are of interest.

Horizontal mass divergence and convergence in the long waves.—In the case of geostrophic flow along parallel straight isobars at any level (or contours on an isobaric surface), or of "gradient flow" round parallel curved isobars, the stream lines will run parallel with the isobars, and will give constant transport capacity of air between the isobars, and there will be no horizontal mass convergence or divergence. In general, however, such conditions do not apply exactly, often not even approximately, and convergence or divergence may arise in two different ways:—

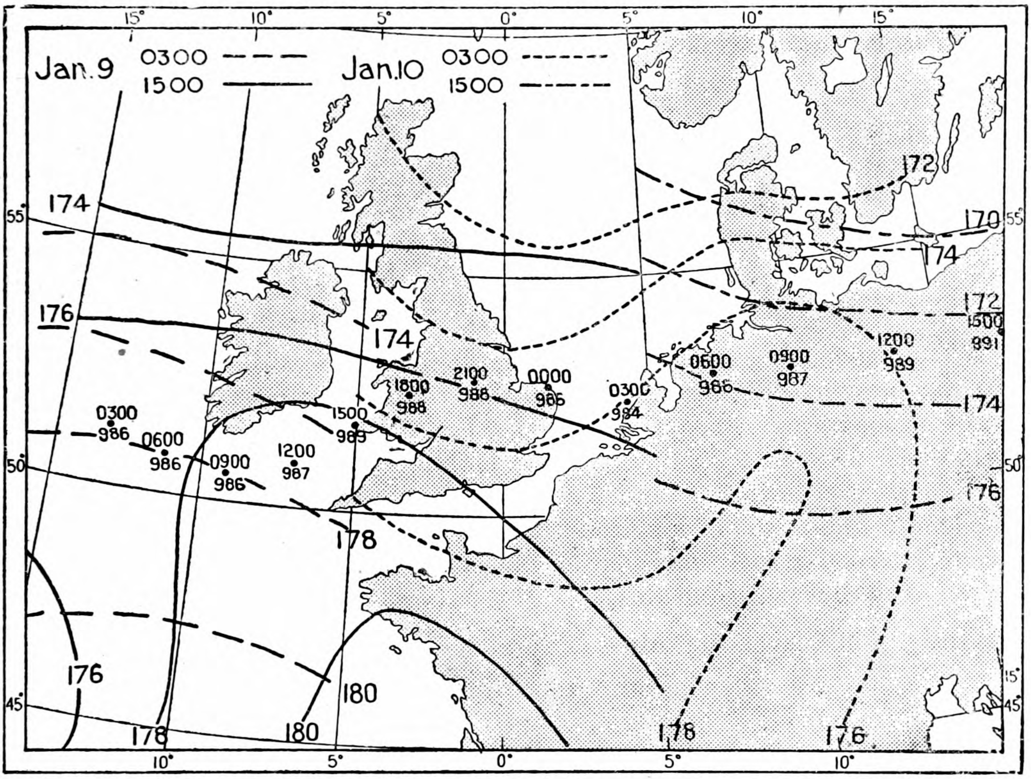

FIG. 6—RELATIVE TOPOGRAPHY OF THE LAYER 1000–500 MB. AT 0300 AND 1500 ON JANUARY 9, 1948, AND AT 0300 AND 1500 ON JANUARY 10, 1948

Thickness contours are at 200-ft. intervals. Positions of the centre of the depression at 3-hourly intervals are also indicated.

(*a*) If the stream lines are not parallel to the isobars, there will generally be a difference between the mass of air entering the area between two isobars in any region and that flowing out across the isobars, giving rise to *transversal* mass divergence (or convergence).

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*BJERKNES, J. and HOLMBOE, J.; On the theory of cyclones. *J. Met., Milton, Mass.*, 1, 1944, p. 1.

(*b*) If the transport capacity between two isobars varies along their length, there will similarly be a difference between the masses of air entering and leaving the region between the isobars, giving rise to a *longitudinal* component.

In the case of wave-shaped isobars (or contours) both these components are of importance.

Transversal mass divergence.—For the tranversal divergence Bjerknes and Holmboe derive the rule that " The transversal divergence and the relative zonal wind ($\bar{v}-c$) have the same sign in the region to the east of the trough and opposite signs in the region to the west of the trough."

Longitudinal mass divergence.—Bjerknes and Holmboe derive for the speed c of a symmetrical wave with no longitudinal divergence a formula of the form

$$\bar{v} - c = v_c$$

where $\bar{v}$ is the mean zonal wind, i.e. the mean of the westerly components through the trough and wedge; and v_c is a critical speed depending mainly on geometrical considerations—the wave-length, the shape of the wave, and the latitude. If $\bar{v} - c > v_c$ there will be a bottleneck at the trough, and convergence to the west of the trough, with divergence to the east; and correspondingly if $\bar{v} - c < v_c$ the bottleneck is at the ridge, with convergence to the east of the trough.

In the present case v_c cannot readily be evaluated theoretically, but some idea of its magnitude may be obtained. For the simpler case of a sinusoidal flow pattern (discussed by Bjerknes and Holmboe) v_c is a function only of the wave-length and latitude; and for the present case (in latitude 50°N., with wave-length about 36° of longitude, and decreasing), v_c is less than 6 m.p.h. It seems reasonable to assume that for our actual case the order of magnitude of v_c is not very different from this.

At the 500-mb. level, the values of $\bar{v}$ and of c were approximately as follows:—

	0300, 9th		1500, 9th		0300, 10th		1500, 10th
$\bar{v}$ (m.p.h.)	40		45		50		55
c (m.p.h.)		50		35		40	

(The value of c during the first interval must be regarded as suspect, because of the inadequacy of data over the Atlantic, and consequent doubt as to the position of the trough at 0300 on the 9th.)

Thus the value of $\bar{v} - c$ was probably negative, and so subcritical, until 1500 on the 9th, and thereafter fairly constant at about 12 m.p.h., and almost certainly supercritical.

Two other points have to be noted:—

(*a*) In the normal case, where the temperature falls from south to north, $\bar{v}$ increases with height, and where the speed of the trough is the same at all heights (as was approximately the case from 1500 on the 9th), we can expect $\bar{v} - c$ to be subcritical at low levels, but supercritical at high levels. The height of the level of non-divergence, where $\bar{v} - c = v_c$, will determine whether the low-level bottleneck at the ridge or the high-level bottleneck at the trough is the more important.

(*b*) In the low-level closed-isobar régime convergence is normal, other factors being small in comparison with surface friction.

Period: 0300 to 1500 on January 9.—During this first phase the depression followed a " normal " course for an occluding secondary, filling slowly, and turning towards the left. This, however, appears to be somewhat fortuitous. Normally, this course of an old depression is associated with the closed circulation reaching to a considerable height (with corresponding preponderance of convergence over any high-level divergence causing rising surface pressure) and cold air being pulled round to the west and south of the depression (causing the upper flow and the track of the centre to back). In the present case, the shallowness of the upper trough and its distance from the surface centre indicate that the closed isobar system extended to no great depth, and another reason for the filling up and the curvature of the track must be looked for.

During this period, the value of $\bar{v} - c$ is doubtful, as indicated earlier, but was probably negative and almost certainly subcritical. In the region of the surface centre, to the east of the upper trough, there would be some convergence in the lower closed circulation and further convergence or, at least, little or no divergence over the upper atmosphere as a whole. With $\bar{v} - c$ negative, there would be transversal convergence at 500 mb. and, provided $\bar{v} - c$ is merely subcritical, there will be longitudinal convergence at this and all lower levels. Consequently rising pressure is to be expected at the surface.

Following the rough rule that the track of the depression is in the general direction of the upper flow, we should expect it to move somewhat north of east. At 0300 the gradient wind, at 500 mb., above the surface centre was about 240° 50 m.p.h., while measured winds were:—

	700 mb.		500 mb.	
	°true	m.p.h.	°true	m.p.h.
Larkhill	250	21	280	52
Valentia	210	25	240	30

The speed of the depression was 30 to 35 m.p.h.

It may be noted that the depression was centred to the east of the upper trough and therefore in a region of south-westerly upper winds. The 500-mb. wind at Larkhill belongs to the region ahead of the next ridge eastward; the winds at Valentia are too light to be typical, as Valentia was somewhat north of the surface centre.

Period: 1500, January 9 to 0300, January 10.—During this period, the fast-moving upper trough having overtaken the surface depression, their interaction becomes the important feature.

The surface depression pulls down colder air from the north on its west side, so tending to develop an upper air trough in this region, which leads, in effect, to a slowing up and deepening of the upper trough.

The reduction of the speed c of the trough means that $\bar{v} - c$ becomes supercritical through the major part of the upper air mass, with consequent preponderance of convergence (and so rising surface pressure) to the west of the trough and of divergence (and falling surface pressure) to the east of the trough.

The longitudinal and transversal components of divergence have the same sign, and augment one another, negative to the west and positive to the east of the trough. The surface-pressure changes indicate an acceleration eastwards of the surface centre into the area east of the upper trough, where the preponderating divergence leads to further deepening. The fact that the track was somewhat south of east might be due to the stronger winds on the south side of the low, leading to the divergence ahead of the trough being more marked towards the south than further north.

Period: 0300 to 1500, January 10.—In this period we are approaching something more like the normal filling-up stage of a depression. The deepening of the upper trough as colder air is drawn in behind the surface low is associated with increasing vertical extent of the surface closed-isobar system; and the convergence in this system outweighs divergence ahead of the trough at greater heights. The rapid eastward movement is still associated with the rapid movement of the upper trough.

Later history of the depression.—During the 24 hours following the period already discussed, the depression continued its rapid eastward movement (at about 40 m.p.h.) to near 55°N. 40°E. at 1500 on January 11. By this time closed isobars extended up to 500 mb., with the axis of the vortex inclined from the vertical towards the north-west. Little further filling had occurred, the pressure at the surface centre being 993 mb. Longitudinal and transversal divergence ahead of the upper trough may account for the failure of the surface low to fill further, and also for the fact that during this last phase it tended to move a little more ahead of the upper trough.

As remarked in an earlier paragraph, a low which extends through a considerable height as a closed circulation will usually tend to turn north-east. However, in the present case the low moved into steadily colder air, and this could account for the continued eastward track.

Conclusion.—This depression caused heavy gales in the early morning of January 10, winds of Beaufort force 8 or 9 being reported over Holland between midnight and 0300, and in the Rhineland between 0300 and 0600. By 0900, gales had already almost completely ceased. These gales were only forecast very late, and their rapid disappearance was also unexpected; it was this that drew particular attention to the apparently eccentric history of the depression, and caused the present note to be prepared. It is of interest that the Central Forecast Office (C.F.O.) bulletin issued about 1630 G.M.T. on the 9th forecast for 1200 on the 10th a position for the centre at 55°N. 2½°E., about 500 miles from its actual position, with a depth of 990 mb.; while as late as the 2230 G.M.T. bulletin the position forecast for 1800 on the 10th was 55°N. 13°E., with a depth of 993 mb., against an actual position of 53½ N. 20°E.

While the present investigation appears to give a reasonable explanation of the development of the depression from the forecaster's viewpoint two major difficulties stand out:—

(*a*) Nothing much could have been attempted in the way of analysis until the contours at 1500 G.M.T. on the 9th were available, which even for the restricted area under consideration would have been late in the evening (the C.F.O. bulletin arrives about midnight).

(*b*) I see no real hope of *timing* the changing phases of the depression's history, of deciding just when, for example, the acceleration and deepening of the second phase would occur or, for that matter, what its extent would be and how long it would last.

At the same time, it is hoped that the investigation may prove of interest, both, in that it provides a rational explanation of synoptic developments over which both the principal British forecast offices in the area went astray, and that it may draw attention to an analytical method which could prove useful on other occasions. It may also provide a warning as to the type of development that can occur where a small depression of little vertical extent is situated below an upper atmosphere with high winds, and especially one with wave-shaped contours moving independently of the surface depression.

METEOROLOGICAL RESEARCH COMMITTEE

The 48th meeting of the Meteorological Research Committee was held at the Meteorological Office, Harrow, on Thursday, May 8, 1947.

The papers considered included a review of progress in the development of meteorological instruments, two papers on the accuracy of radar methods of wind measurement, a note on balloon soundings up to a height of 30 Km., and a paper on the prediction of evaporation from saturated surfaces.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held at 49 Cromwell Road, on April 19, 1948, the Symons Memorial Lecture was delivered by Dr. H. G. Booker on the subject " Some problems of radio meteorology ".

Dr. Booker, one of the leading workers during the war on the propagation of high-frequency electromagnetic waves through the atmosphere, began his lecture by stating that the problems he would deal with were those found in the refraction of short radio waves of length less than 10 m. in the lower layers of the atmosphere. When there was a steep gradient of temperature or humidity these short waves were refracted with exceedingly important effects.

To demonstrate the effects of refraction slides were projected showing the areas, around Malta, visible on a radar screen on the island on days of normal propagation with little refraction and those visible on a day when the refraction was such as to produce abnormally long-range radar vision. Dr. Booker pointed out, from these slides, that abnormally long-range vision was more of a nuisance than a help since it made the reflections, it was desired to see, of high-flying aircraft invisible against a background of unwanted ground echo and could show confusing echoes of points, beyond the range for which the apparatus was calibrated, appearing as " second-sweep " echoes at half their proper distance. Other slides showed echoes from up to 200 miles, obtained at night by radar near Calcutta when a radiation inversion produced abnormal refraction compared, with those from only 30 miles by day when refraction was small. The most striking effects, however, were revealed in a slide showing, during the hot season, echoes obtained by radar at Bombay from the Arabian coast over 1,000 miles away, the same radar having a range of only 15 miles under normal conditions.

These abnormal effects occurred, Dr. Booker pointed out, when the high-frequency waves, which normally travelled in straight lines, were bent down towards the surface of the earth. In a dry atmosphere an increase of temperature with height at the rate of 6°F./100 ft. imposed a degree of downward bending on the rays equal to the curvature of the earth. A decrease of humidity mixing ratio with height of $\frac{1}{2}$ gm./Kg./100 ft. would have the same result. Often the two effects of temperature and humidity acted together so producing an even greater degree of bending. If the conditions favourable for downward bending occurred only in a narrow belt near the surface of the earth, then high-frequency waves would be trapped within the belt which thereby formed a species of radio duct guiding the waves. The energy of waves of long wave-length, on the other hand, would leak out of the top of the duct. Long waves, in fact, are affected only by the meteorological conditions over a great depth of the atmosphere. For waves of 1-m. wave-length the suitable conditions must extend up to 500 ft. to be effective in trapping the energy, but for waves of 10 cm. they need extend up to only 100 ft.

The height of the layer containing the conditions favourable for downward bending was as important as its depth since a high layer could only refract the waves downwards when they met it at a glancing incidence and the higher the layer the greater the angle of incidence of the rays from a transmitter on the ground. Such layers at heights of over 5,000 ft. were of little importance in radio propagation.

Dr. Booker then turned to the meteorological circumstances in which steep inversions of temperature and/or steep lapses of humidity could occur. There were three types, (*a*) nocturnal radiation overland, (*b*) movement of air from land to sea, and (*c*) subsidence. In the case of nocturnal inversions the humidity often tended to increase with height so partly or wholly nullifying the effect of the inversion while in the case of subsidence the inversion was often too high. Movement of warm dry air from land to sea gave the most spectacular effects, such as those found over the Arabian Sea in the hot season. It was also of great practical importance since many radar stations were necessarily located on the coast looking out over the sea.

The radio worker, Dr. Booker pointed out, needs very precise information on the vertical gradients of temperature and humidity for calculating the effective range of his transmitters. In special experiments detailed measurements of these gradients can be made but they cannot be made everywhere it is proposed to establish new transmitters. Dr. Booker emphasised that a general theory from which the temperature and humidity gradients can be deduced from the ordinary meteorological surface observations of temperature, humidity and wind is urgently needed. This was essentially, in his view, a problem in eddy diffusion. During the war efforts had been made to solve the diffusion equation but with only moderate success. After the assumption of constant coefficient of turbulence had been tried and found of no value, he had worked with the conjugate power laws of O. G. Sutton in which the horizontal velocity is taken as varying as z^m (z = height, $0 < m < 1$), and the coefficient of turbulence as z^{1-m}. The differential equation for diffusion in air flowing from a warm land to a cool sea could be solved with this assumption, but there was a serious difficulty in lack of information about the value of the index m, except that it was likely to be about zero in unstable conditions and unity in

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O.W.S
WEATHER RECORDER

Reproduced by courtesy of Capt. A. W. Ford

THE SHIP'S CREW OF O.W.S. *Weather Recorder*

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O.W.S. *Weather Observer*
Taken from the *Weather Recorder.*

very stable conditions. Comparisons of observed profiles of potential temperature and humidity in air flowing from land to sea were made with calculated profiles and the best values of *m* deduced. It was found that the values of *m* obtained from the profiles of potential temperature were closely correlated (correlation coefficient : 0·9) with those found from the humidity profiles. A less satisfactory result was that the expected connexion between the value of *m* and the difference between the potential temperature at the ground and at a height could not be found. What was found was that the value of *m* increased with the height to which the diffusion had reached. The conjugate power law was, thus, not very satisfactory.

On solving the differential equation it was found that the gradients of temperature and humidity were very sensitive to the variation of the coefficient of turbulence with height but insensitive to the variation of wind. An attack on the coefficient of turbulence was therefore the next step. General considerations showed that the coefficient should increase with height in the lowest layers, reach a maximum at some hundreds of feet, and then decrease again. Such a kind of variation with height explained the dependence of the value of *m* in the power-law theory on the height which diffusion had reached.

Finally, Dr. Booker pointed out that the differential equation for the variation of potential temperature and humidity with height in a subsidence inversion was simpler than the corresponding equations for radiation and advection inversions and suggested that, on that account, subidence inversions should be investigated before the nocturnal and radiation ones.

NOTES AND NEWS

Ocean weather ships

Opposite is a photograph of the *Weather Observer* taken from the *Weather Recorder*, and facing p. 136 is a photograph of the crew of the *Weather Recorder* which was concerned in the rescue of the crew of a Norwegian ship off the west coast of Scotland. An account of the rescue, given by Captain A. W. Ford of the *Weather Recorder*, is given below.

Rescue of Crew of S.S. " Veni "

Upon completion of fuelling the O.W.S. *Weather Recorder* sailed from the Tail of the Bank at 1608 G.M.T. on January 10 for Station " I ". The wind was increasing in force until, by midnight, a SE. whole gale was blowing with a heavy south-easterly sea. Ship was rolling and pitching heavily.

Off Rathlin Island at 0012 on the 11th, an S.O.S. was intercepted from the Norwegian steamer *Veni*: " Position Torran Rocks west of Colonsay sinking must try leave." This was received at 0047. Course was set for the Torran Rocks and speed increased to 150 revolutions. The following signal was sent to the *Veni* via Malin Head who was controlling the distress: "Am proceeding to your assistance with the utmost dispatch. Will be with you at 0500." Further signals and D.F. bearings were received which placed the ship on the west side of Colonsay. The radar was checked and rechecked all the way to the distress and it was found that it was working well, provided that the aerial was lined with the P.P.I. mask each time we altered course. I didn't feel completely happy about the location of the wreck; so the searchlight was flashed into the air when the north end of Islay was reached and the *Veni* responded with red rocket flares. Course was altered into the shore a couple of miles away.

While all this was going on the lifeboat was prepared, the engine tried every half-hour, scramble and floater nets prepared, also the rubber dinghys, whilst the sick bay was prepared for any casualties. The night was pitch black and the gale worse than ever; to make matters worse terrific heavy rain kept on blotting out our only navigational light, that of Dubh Artach. Full use was made of the radar and the echo-sounding machine, and we closed the wreck to inside a mile. Many signals had been passed between the ships, the Master of the *Veni* giving me all the latest news of the position. As it was only a couple of hours to daylight the Master of the *Veni* signalled he would wait until daylight. The *Weather Recorder* stood off to westward at a mile to a mile and a half distant. I requested the Master to inform me if he required me to use my boat, but it could be seen that the *Veni* had her boats in the water by the lanterns in them.

Red flares were sighted so I thought there must be something doing; I closed the wreck again and the flares were obviously from the boats. The boats steered to northward under oars and I came around, close to the wreck, stemming the wind. The sea had dropped and no difficulty was experienced in getting the survivors on board, who were fed and bedded down. Only one injured man was taken to the sick bay. His wounds were washed and dressed; he appeared quite comfortable.

At 0700 we informed Malin Head who cleared the distress; the Port Patrick lifeboat was informed that his services would not be required. Course was set for Greenock and speed at 160 revolutions. The weather had moderated considerably, Greenock was reached at 1800 on the 11th. All the officials met the ship and the survivors were taken to the Clydesdale Sailors' Home.

Without the radar it would have been impossible to close the wreck. It was very tiresome having to line up the aerial each time we altered course, but it was achieved. The crews were very keen and nearly all wanted to man the lifeboat.

A. W. FORD
Master, Ocean Weather Service

O.W.S. "Weather Recorder", Greenock, January 14, 1948.

Severe local thunderstorm, Lough Foyle area

Thanks are due to Mr. J. Porter of the rainfall station Moneydig, Garvagh, Co. Londonderry, for calling attention to what he describes as " one of the worst local thunderstorms " which " swept parts of Co. Londonderry and Tyrone during the morning of July 28, 1947."

Press accounts and rainfall records confirm that the storm of approximately 3-hr. duration, was confined to a comparatively small area of Northern Ireland and was contained within the mountains surrounding Lough Foyle, of which the Sperrins form the main boundary to the east and south.

The three rain-gauges in the coastal plain at the foot of the hills in the storm area, i.e. Ballykelly, Castle Rock and Dungiven, recorded 2·37 in. (60·2 mm.) 2·14 in. (54·4 mm.), and 1·12 in. (28·5 mm.) respectively during the period of the storm. It is very probable that even greater amounts of rain fell in the hilly districts in the vicinity, but outside this local area, little or no rain was recorded by the many rain-gauges in Northern Ireland.

The beds of small streams which normally flow from the surrounding hills to Lough Foyle, were unable to contain the sudden increase in the volume of water and severe flooding occurred in many places. The onrush of water caused very considerable damage which was described by the local press as "the most severe visitation in living memory."

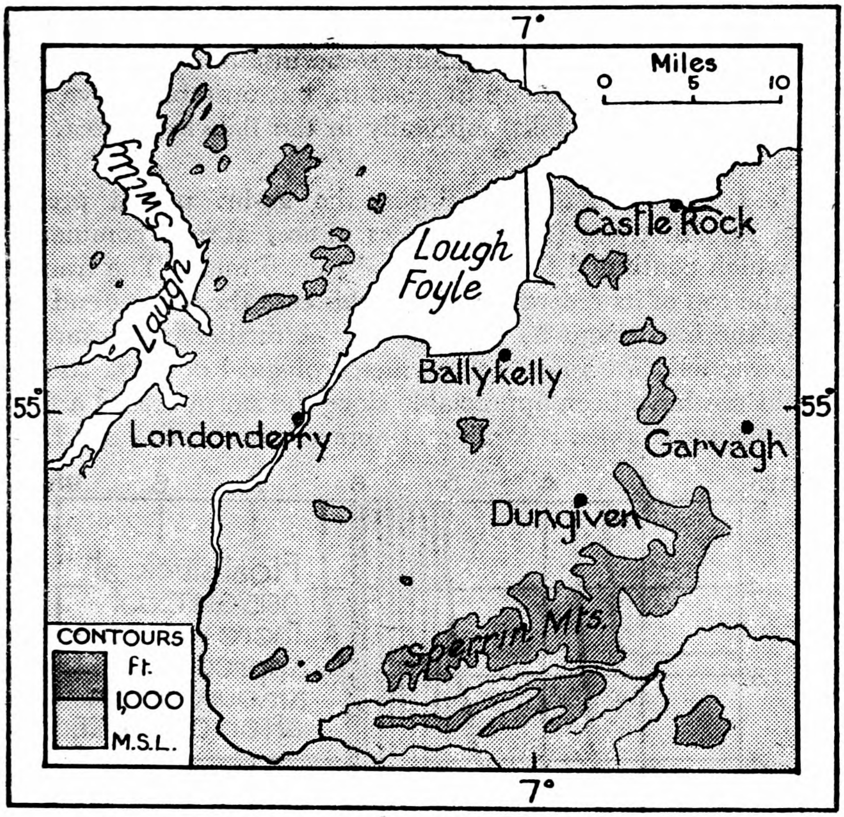

FIG. I—MAP OF THE AREA ROUND BALLYKELLY

A published report by the County Surveyor of the districts concerned, given to a Rural Council on October 6, 1947, after the most thorough investigation lasting two months, stated that "the thunderstorm of July 28 caused devastation unparalleled in the records of the district. Deluges of flood water, which followed torrential rain and cloudbursts, washed away miles of road and their foundations. Many others were made impassable by hundreds of tons of debris. Many large bridges and culverts were damaged or completely washed away. Some roads were so badly damaged that a considerable mileage would require complete reconstruction."

The following account of the storm is taken from a report from H.Q., R.A.F.N.I., Aldergrove:—

"A thunderstorm with heavy rain resulted in flooding of the airfield at Ballykelly on the morning of July 28, 1947. The rainfall during a 3-hr. period (5.15 a.m. D.B.S.T. to 8.15 a.m. approximately) amounted to 2·37 in. (60·2 mm.). The heaviest fall occurred between 7 a.m. and 8 a.m., when the recorded rainfall was 1·68 in. (42·6 mm.). This constitutes a ‘ remarkable ’ fall. Within two hours of the cessation of the heavy rainfall, flood water from a near-by river which had burst its banks, spread over the airfield to a depth of 2 ft. in places. The pressure distribution at the time was fairly uniform generally over the British Isles, with very shallow lows forming over Ireland. A weak front had moved slowly south on the previous day, become stationary across mid Ireland, and later dissipated. Surface winds were light variable or easterly, and between S. and SW. 20–30 kt. above 10,000 ft. over Northern Ireland. Maximum surface temperatures on the 27th were mainly of the order 62° to 66°F. over most of Ireland, but reached 74° to 75°F. locally in central and west-central Ireland, causing some instability in the lowest layer. Previously, air was fairly stable up to 3,000 ft., but unstable above that height. The uplift of air over high hills, especially in the Ballykelly area, might well have been a contributory cause.”

No rain had fallen at Ballykelly during the 24-hr. period preceding the storm. The rainfall trace (Fig. 2) shows almost abrupt commencement of heavy rain which continued for a period of 3 hr. 6 min. The trace also ends abruptly at the top of its recording, but in this case the abrupt end was due to immersion of the instrument by flood water. A further unmeasured quantity of rain obviously fell, but a note by the meteorological observer states that this amount could not have been appreciable since the storm ceased a few minutes after the rain-gauge stopped recording at approximately 0615 G.M.T.

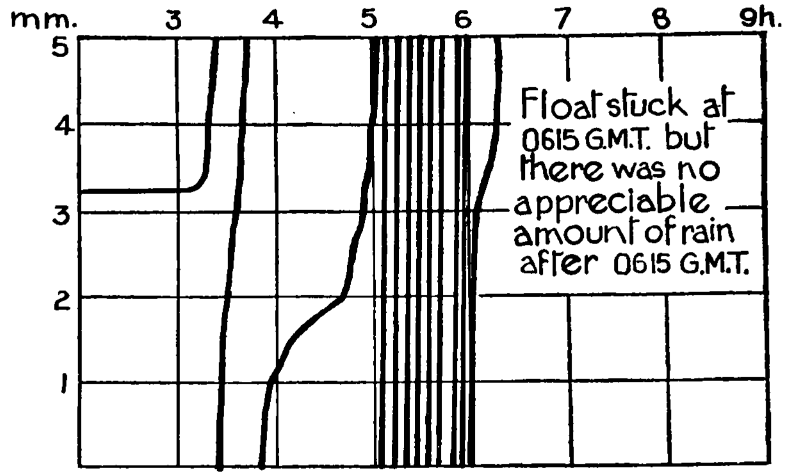

FIG. 2—COPY OF THE RAINFALL TRACE AT BALLYKELLY, JULY 27, 1947

Photographs (facing p. 129) were taken at the R.A.F. station, Ballykelly, two days after the airfield became flooded. Fig. 3 was taken from the Control Tower. The Lancaster aircraft shown in the photograph had previously been marooned and had just taken off, having used one runway which, for the first time in three days, had become partly clear of water. Fig. 4 was also taken on July 30 after the floods had subsided somewhat. It will be seen that the meteorological instruments enclosure, which was covered to a depth of 2 ft. on the morning of July 28, was still surrounded by water.

At Garvagh, which is on the north-eastern side of the Sperrin Mountains, only ·03 in. (0·76 mm.), were recorded during the storm.

A. WALTERS

WEATHER OF APRIL 1948

From the 1st to the 8th deep depressions, with associated troughs, passed across or near to the British Isles. From the 9th to the 16th pressure was relatively high, after which there followed a week with irregular shallow depressions. From the 24th to the 27th there was a second period with high barometer, but after the 27th the anticyclone moved away to the south-west and an irregular system of depressions spread in from the north-west.

The mean-pressure map for the month shows a large high-pressure area extending from Portugal westwards to the American coast, with pressure about 1025 mb. near the Azores, and an area with pressure below 1010 mb. extending eastwards from southern Greenland to Finland and southwards to include most of Scotland and Norway. Pressure was below the average over most of north-west Europe, and in Greenland, Iceland and Spitsbergen; it was above the average over a large area centred north-west of the Azores and including the eastern parts of North America south of Labrador.

The weather over the British Isles was generally warm and sunny, with rainfall not very different from the average on the whole. Unsettled weather prevailed until the 9th, when a ridge of high pressure moved in over the country. Subsequently conditions were mainly anticyclonic until the 16th, apart from occasional slight rain in the north and west. A spell of warm, thundery weather ensued, which was followed by another spell of fair sunny conditions. The closing days were cool and rather unsettled with shallow depressions moving south-east across the country. The range of pressure was exceptionally great for April; at 0300 on the 1st pressure fell to 953 mb. in the Hebrides and on the 26th it reached 1043 mb. in Ireland. Mean temperature again appreciably exceeded the average, the excess being roughly between 2° and 3°F. In England and Wales this was the thirteenth successive month for which the mean temperature exceeded the average for the period 1906–35. So long a series of consecutive warm months has not occurred since comparable values were available, that is, since 1901. The first six days and the last three were relatively cold, while the warmest week was that ending on the 24th.

Rainfall exceeded the average over most of Scotland except in the east and in the south-west coastal districts. In England and Wales more than the average occurred in an area extending from Essex across the southern Midlands to mid Wales, in an area in the extreme north, over parts of the south-west and in small scattered areas elsewhere. In Northern Ireland more than the average occurred at Londonderry and Armagh and less than the average elsewhere. The duration of bright sunshine was substantially in excess of the average except locally in the west and north of Scotland; at Croydon it was the sunniest April since records started in 1922 and at Hampstead the sunniest since 1914.

The general character of the weather is shown by the following table:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	74	19	+2·5	96	−1	127	46
Scotland	68	19	+2·3	115	+1	107	36
Northern Ireland ..	67	30	+2·9	90	−1	112	40

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, DECEMBER 1947

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and ½ Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1015·9	+3·3	55	23	46·0	38·3	42·1	+0·6	40·4	86	7·8	2·14	−0·15	14	0·7	8
Gibraltar	1020·5	+0·2	70	44	63·3	50·6	56·9	+0·9	52·0	82	3·6	3·22	—	8	—	—
Malta	1013·3	−2·9	71	42	60·5	51·7	56·1	−1·8	53·4	72	6·4	3·13	—	20	5·5	56
St. Helena	1014·9	—	70	55	67·1	57·0	62·1	+1·2	57·2	95	9·4	0·88	−0·45	11	—	—
Freetown, Sierra Leone	1010·5	+1·1	88	70	83·5	74·7	79·1	−0·8	73·9	81	5·4	2·53	+1·11	10	6·7	58
Lagos, Nigeria ..	1010·3	−0·2	92	66	88·5	70·8	79·7	−2·1	76·5	89	8·1	1·62	—	5	5·5	47
Kaduna, Nigeria ..	1009·9	—	94	53	90·2	57·9	74·1	−0·2	58·1	27	2·9	0·00	0·00	0	9·6	84
Chileka, Nyasaland ..	1012·5	−0·2	91	64	82·8	67·7	75·3	−0·8	69·5	75	7·3	4·87	−0·85	17	5·9	45
Salisbury, Rhodesia..	1010·9	−0·5	82	57	78·5	60·5	69·5	−0·1	62·5	71	6·7	5·31	−1·79	17	6·4	49
Cape Town ..	1014·7	+0·4	95	54	77·8	60·6	69·2	+1·3	60·8	63	3·7	0·51	−0·30	4	—	—
Germiston, South Africa	1011·6	—	83	48	76·3	56·7	66·5	—	58·6	70	5·6	5·16	—	15	7·7	57
Mauritius	1013·9	+0·2	90	68	85·5	71·2	78·3	0·0	72·3	76	4·7	3·23	−1·45	16	10·1	76
Calcutta, Alipore Obsy.	1014·7	−0·9	86	51	79·4	58·6	69·0	+2·5	59·5	82	3·5	1·05	+0·81	6	6·7	62
Bombay	1012·2	−1·3	92	65	88·3	69·7	79·0	+1·6	66·9	72	0·8	0·00	−0·05	0	9·7	89
Madras	1012·2	−1·3	86	64	83·3	69·1	76·2	−0·5	70·3	87	5·7	0·57	−4·78	5	7·5	66
Colombo, Ceylon ..	1010·7	+0·4	87	67	84·8	71·9	78·3	−1·2	71·5	86	5·9	5·31	+0·19	8	7·0	60
Singapore	1009·7	0·0	88	70	84·8	72·7	78·7	−1·2	76·3	85	—	17·93	+7·37	21	—	—
Hongkong	1019·8	+0·1	83	42	70·0	57·6	63·8	+0·8	58·1	73	—	0·35	−0·68	11	5·6	52
Sydney, N.S.W. ..	1010·9	−1·0	94	58	76·3	63·7	70·0	−0·1	64·8	70	6·5	8·44	+5·58	21	6·4	45
Melbourne	1010·1	−2·6	98	50	74·7	55·1	64·9	+0·1	57·8	59	7·1	3·91	+1·64	14	6·2	42
Adelaide	1011·4	−1·9	99	49	78·7	58·1	68·4	−2·7	58·6	49	5·7	1·78	+0·75	11	8·2	57
Perth, W. Australia..	1013·7	+0·5	100	53	77·5	57·6	67·5	−3·3	60·5	55	4·0	0·35	−0·21	5	10·9	76
Coolgardie	1011·8	+0·6	105	47	90·3	58·9	74·6	−1·1	58·8	43	2·7	0·00	−0·69	0	—	—
Brisbane	1011·8	−0·2	93	62	82·6	67·0	74·8	−1·6	68·5	71	6·2	8·14	+3·25	18	8·1	59
Hobart, Tasmania ..	1009·6	−0·1	83	42	68·7	51·7	60·2	0·0	54·5	63	8·0	4·91	+2·92	16	7·0	46
Wellington, N.Z. ..	1016·8	+4·6	—	43	67·6	53·4	60·5	+1·5	57·3	74	7·9	1·62	−1·60	11	7·0	46
Suva, Fiji	1007·3	−1·3	88	70	85·8	73·1	79·5	+0·5	75·5	85	6·9	5·88	−6·64	19	6·6	50
Apia, Samoa ..	1007·8	−0·5	88	72	85·8	74·6	80·2	+0·9	77·5	78	8·2	18·44	+4·55	22	5·5	43
Kingston, Jamaica ..	1013·6	−0·4	91	66	87·1	70·2	78·7	+1·0	71·7	70	3·7	1·56	−0·03	5	7·7	69
Grenada, W. Indies..	1011·4	−0·4	87	65	85·0	75·1	80·1	+1·0	75·8	79	5·5	2·70	−4·50	23	—	—
Toronto	1018·5	+0·9	47	7	32·8	21·1	26·9	−0·2	24·3	—	7·0	2·39	−0·08	15	2·8	31
Winnipeg	1019·4	+0·7	33	−29	13·4	−4·2	4·6	−1·2	2·6	—	6·1	1·85	+0·91	14	2·4	29
St. John, N.B. ..	1010·4	−3·6	48	4	29·4	16·3	22·9	−1·5	19·1	—	5·6	2·91	−1·26	14	4·3	49
Victoria, B.C. ..	1016·5	−0·2	51	28	46·5	35·9	41·2	+0·1	38·5	93	7·3	8·41	+2·67	25	1·3	15

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, YEAR 1947

STATIONS	PRESSURE		TEMPERATURES							REL-ATIVE HUM-IDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
	Mean of day M.S.L.	Diff. from normal	Absolute		Mean values							Total	Diff. from normal	Days	Daily Mean	Per-centage of possible
			Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb							
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1015·1	+0·1	91	15	57·2	44·3	50·7	+0·3	47·2	79	7·3	19·74	−4·06	150	3·7	28
Gibraltar	1017·0	−0·9	98	40	72·4	60·1	66·3	+2·1	61·7	83	5·0	29·47	—	80	—	—
Malta	1014·9	−0·5	95	42	73·2	60·7	66·9	+0·8	62·5	65	4·1	8·99	—	63	8·8	72
St. Helena	1016·3	—	80	51	65·4	57·2	61·3	+0·6	57·5	96	9·2	41·25	+11·23	254	—	—
Freetown, Sierra Leone	1011·6	+1·8	90	69	84·1	75·3	79·7	+0·6	75·4	84	6·8	151·48	−5·75	175	6·0	49
Lagos, Nigeria ..	1011·7	+0·9	96	61	87·7	71·6	79·7	−1·0	76·9	87	8·2	69·93	—	134	4·6	38
Kaduna, Nigeria ..	1010·3	—	100	52	89·1	65·5	77·3	+0·1	66·5	55	5·9	46·23	−12·60	106	7·7	64
Chileka, Nyasaland																
Salisbury, Rhodesia																
Cape Town	1017·5	+0·5	103	36	71·6	54·9	63·2	+0·9	56·1	76	4·5	22·60	−2·44	115	—	—
Germiston, South Africa	1016·9	—	92	24	73·2	50·2	61·7	—	51·6	57	3·0	23·99	—	95	9·0	74
Mauritius	1016·1	0·0	94	55	81·3	68·1	74·6	+0·6	68·7	76	5·0	33·15	−16·60	212	8·4	69
Calcutta, Alipore Obsy.	1007·2	−0·4	108	50	89·4	72·3	80·8	+2·0	72·6	84	4·8	67·04	+2·72	123	7·0	58
Bombay	1008·4	−0·8	99	62	87·7	74·7	81·2	+0·6	73·5	81	4·6	77·09	+4·90	96	7·9	65
Madras	1008·4	−0·4	107	64	90·9	76·0	83·5	+0·4	75·0	78	5·8	34·79	−14·77	72	7·9	65
Colombo, Ceylon ..	1010·1	+0·4	92	65	86·1	75·1	80·7	−0·3	74·9	86	6·8	90·68	+10·55	173	6·9	57
Singapore	1009·1	−0·4	93	70	87·1	74·2	80·7	−0·2	77·5	84	—	121·43	+26·31	205	—	—
Hongkong	1013·3	+0·8	95	42	77·1	67·5	72·3	0·0	67·9	81	—	102·03	+16·30	178	4·8	40
Sydney, N.S.W. ..	1016·5	+0·6	94	39	70·8	56·5	63·6	+0·5	57·9	70	5·5	41·05	−6·43	137	6·9	57
Melbourne	1015·2	−1·1	103	32	68·3	50·3	59·3	+0·9	52·5	65	6·7	30·47	+5·00	163	5·3	44
Adelaide	1016·7	−0·4	105	38	71·7	53·4	62·5	−0·5	54·7	57	6·1	21·69	+0·54	145	6·3	51
Perth, W. Australia	1015·6	−0·8	100	37	73·4	54·9	64·2	0·0	57·7	61	4·5	43·42	+9·05	137	7·9	66
Coolgardie	1016·0	+0·1	106	31	77·0	52·8	64·9	+0·4	53·4	57	3·5	8·40	−1·87	60	—	—
Brisbane	1016·5	+0·6	93	40	76·4	59·2	67·8	−1·1	61·2	64	5·0	49·06	+3·77	127	7·4	62
Hobart, Tasmania	1012·3	−0·2	93	33	62·9	46·8	54·9	+0·5	49·0	66	7·1	38·61	+14·82	180	6·2	51
Wellington, N.Z. ..	1015·8	+1·1	—	32	60·4	48·2	54·3	+0·3	51·3	78	7·4	51·70	+3·66	150	5·7	47
Suva, Fiji	1011·3	0·0	92	62	82·4	72·0	77·2	+0·2	73·2	83	7·2	120·79	+3·65	235	5·4	45
Apia, Samoa ..	1010·1	−0·2	91	67	86·7	74·2	80·5	+2·0	77·2	79	6·2	127·79	+18·08	222	7·0	58
Kingston, Jamaica	1014·1	+0·4	96	65	87·9	72·7	80·3	+1·0	73·6	71	3·5	27·82	−5·77	63	8·5	70
Grenada, W. Indies	1013·1	+0·7	88	65	85·4	75·7	80·5	+1·6	76·2	79	6·8	45·74	−28·85	218	—	—
Toronto	1015·9	−0·7	93	0	55·2	39·5	47·3	+2·1	40·9	77	6·4	29·91	−1·38	129	5·3	43
Winnipeg	1015·3	−0·9	96	−29	45·7	26·0	35·9	+1·3	28·5	85	6·1	21·96	+1·78	144	5·6	45
St. John, N.B. ..	1013·9	−0·7	82	−10	50·8	35·6	43·2	+2·0	38·5	86	6·5	42·70	−5·38	156	5·4	44
Victoria, B.C. ..	1017·0	+0·3	85	5	58·3	40·9	49·6	+0·2	43·2	92	5·7	37·62	+7·31	148	6·1	50

RAINFALL OF APRIL 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square	1·68	109	*Glam.*	Cardiff, Penylan	2·64	106
Kent	Folkestone, Cherry Gdns.	1·71	103	*Pemb.*	St. Ann's Head	2·70	132
,,	Edenbridge, Falconhurst	1·42	76	*Card.*	Aberystwyth	1·71	83
Sussex	Compton, Compton Ho.	2·14	107	*Radnor*	Bir. W. W., Tyrmynydd	4·11	111
,,	Worthing, Beach Ho.Pk.	1·28	82	*Mont.*	Lake Vyrnwy	..	..
Hants	Ventnor, Roy. Nat. Hos.	1·33	79	*Mer.*	Blaenau Festiniog	4·38	71
,,	Bournemouth	1·53	85	*Carn.*	Llandudno	1·18	70
,,	Sherborne St. John	1·58	89	*Angl.*	Llanerchymedd	1·56	71
Herts.	Royston, Therfield Rec.	1·41	90	*I. Man.*	Douglas, Boro' Cem.	2·28	93
Bucks.	Slough, Upton	1·64	115	*Wigtown*	Port William, Monreith	1·73	79
Oxford	Oxford, Radcliffe	1·67	104	*Dumf.*	Dumfries, Crichton R.I.	3·56	151
N'hant.	Wellingboro', Swanspool	1·55	104	,,	Eskdalemuir Obsy.	4·41	130
Essex	Shoeburyness	1·38	114	*Roxb.*	Kelso, Floors	2·23	142
Suffolk	Campsea Ashe, High Ho.	1·33	94	*Peebles*	Stobo Castle	3·44	165
,,	Lowestoft Sec. School	1·19	80	*Berwick*	Marchmont House	1·96	97
,,	Bury St. Ed., Westley H.	1·49	97	*E. Loth.*	North Berwick Res.	1·35	96
Norfolk	Sandringham Ho. Gdns.	·81	53	*Midl'n.*	Edinburgh, Blackf'd. H.	1·48	101
Wilts.	Bishops Cannings	1·45	72	*Lanark*	Hamilton W. W., T'nhill	2·89	155
Dorset	Creech Grange	1·70	79	*Ayr*	Colmonell, Knockdolian	1·51	60
,,	Beaminster, East St.	2·18	92	,,	Glen Afton, Ayr San	3·90	130
Devon	Teignmouth, Den Gdns.	2·17	108	*Bute*	Rothesay, Ardencraig	2·80	94
,,	Cullompton	3·23	142	*Argyll*	L. Sunart, Glenborrodale	4·64	111
,,	Barnstaple, N. Dev. Ath.	2·00	94	,,	Poltalloch	2·62	87
,,	Okehampton, Uplands	3·07	96	,,	Inverary Castle	6·73	146
Cornwall	Bude School House	1·95	103	,,	Islay, Eallabus	2·77	97
,,	Penzance, Morrab Gdns.	2·87	118	,,	Tiree	2·10	85
,,	St. Austell, Trevarna	2·83	100	*Kinross*	Loch Leven Sluice	2·21	115
,,	Scilly, Tresco Abbey	2·62	134	*Fife*	Leuchars Airfield	1·42	89
Glos.	Cirencester	2·30	123	*Perth*	Loch Dhu	5·45	115
Salop.	Church Stretton	1·93	89	,,	Crieff, Strathearn Hyd.	1·40	64
,,	Cheswardine Hall	1·56	89	,,	Blair Castle Gardens	2·51	119
Staffs.	Leek, Wall Grange P.S.	1·69	82	*Angus*	Montrose, Sunnyside	1·00	55
Worcs.	Malvern, Free Library	2·07	115	*Aberd.*	Balmoral Castle Gdns.	1·55	72
Warwick	Birmingham, Edgbaston	1·96	113	,,	Dyce, Craibstone	1·52	74
Leics.	Thornton Reservoir	1·74	102	,,	Fyvie Castle	1·79	84
Lincs.	Boston, Skirbeck	1·16	86	*Moray*	Gordon Castle	1·58	90
,,	Skegness, Marine Gdns.	·91	68	*Nairn*	Nairn, Achareidh	2·37	169
Notts.	Mansfield, Carr Bank	1·53	88	*Inv's*	Loch Ness, Foyers	3·77	142
Ches.	Bidston Observatory	1·11	68	,,	Glenquoich	8·06	124
Lancs.	Manchester, Whit. Park	1·41	73	,,	Fort William, Teviot	6·64	148
,,	Stonyhurst College	2·57	95	,,	Skye, Duntuilm	3·36	103
,,	Blackpool	1·28	68	*R. & C.*	Ullapool	3·57	118
Yorks.	Wakefield, Clarence Pk.	1·51	90	,,	Applecross Gardens	4·92	144
,,	Hull, Pearson Park	2·05	131	,,	Achnashellach	8·05	150
,,	Felixkirk, Mt. St. John	1·42	85	,,	Stornoway Airfield	3·88	135
,,	York Museum	1·55	97	*Suth.*	Lairg	3·06	132
,,	Scarborough	1·07	69	,,	Loch More, Achfary	6·31	130
,,	Middlesbrough	·71	52	*Caith.*	Wick Airfield	1·62	81
,,	Baldersdale, Hury Res.	3·11	129	*Shet.*	Lerwick Observatory	3·01	131
Norl'd.	Newcastle, Leazes Pk.	1·72	108	*Ferm.*	Crom Castle	1·63	64
,,	Bellingham, High Green	2·46	114	*Armagh*	Armagh Observatory	2·50	119
,,	Lilburn Tower Gdns.	1·93	97	*Down*	Seaforde	2·03	77
Cumb.	Geltsdale	2·25	106	*Antrim*	Aldergrove Airfield	1·85	88
,,	Keswick, High Hill	2·54	83	,,	Ballymena, Harryville	1·54	58
,,	Ravenglass, The Grove	2·19	88	*Lon.*	Garvagh, Moneydig	2·26	93
Mon.	Abergavenny Larchfield	2·61	103	,,	Londonderry, Creggan	3·42	133
Glam.	Ystalyfera, Wern House	3·06	81	*Tyrone*	Omagh, Edenfel	2·34	89

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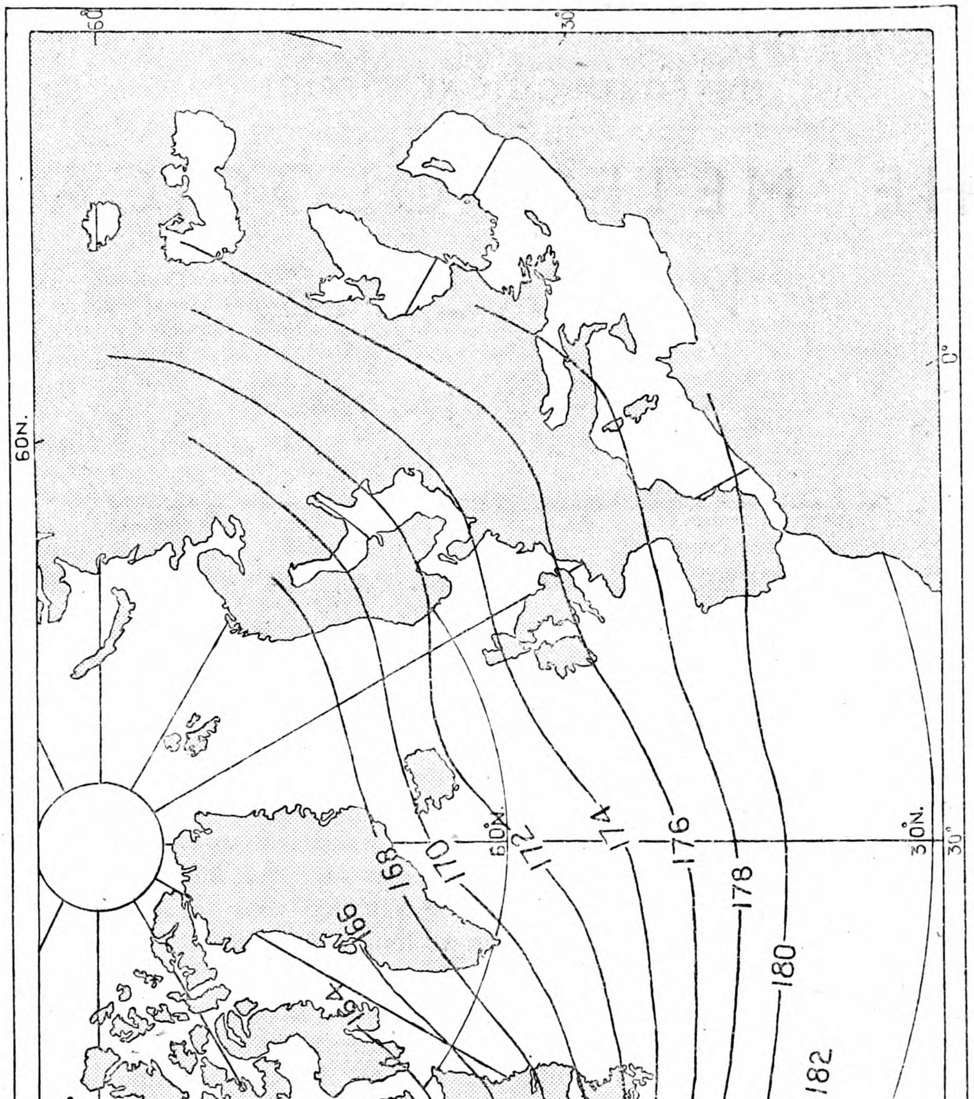
THE USE OF UPPER AIR THICKNESS PATTERNS IN GENERAL FORECASTING

The Monday evening discussion on April 19, 1948, was devoted to upper air thickness patterns and was opened by Dr. R. C. Sutcliffe:—

I have chosen this subject for the meeting not because I shall be able, in the limited time allotted to me, to give a statement of any important new discoveries but because I believe it will prove a stimulating subject for discussion. Routine upper air analysis using isobaric contour charts is a relatively modern departure in our service but in case any forecaster present imagines that it is the latest discovery in synoptic meteorology it should be recalled that the fundamental principles were available in text-book form as long ago as 1910. In Part I of " Dynamical meteorology and hydrography ", V. Bjerknes discussed the subject in some detail and gave examples of synoptic charts at 100-mb. intervals to 300 mb. with both absolute and relative topographies; the word " thickness " was here introduced. So far as I know the introduction into routine aerology came first in Germany some years before the recent war; we adopted the technique in 1941, and in 1947 the International Meteorological Organization agreed to recommend the system for world-wide use.

The chart of relative topography, or thickness chart, with which I am now especially concerned represents by isopleths (thickness lines) the geopotential height difference between standard isobaric surfaces. With the hydrostatic assumption, which is one of the most justifiable among the many approximations used in synoptic meteorology, the thickness is a function only of the (virtual) temperature distribution in the vertical air column; it is, in fact, strictly proportional to the average specific volume of the column. Thus the lines are for practical purposes mean isotherms.

Probably most of us have gained familiarity with thickness charts in the step-by-step construction of upper contour charts and it is sometimes stated that we obtain, say, the 700-mb. chart by adding, graphically, the 1000 to 700-mb. thickness to the 1000-mb. contours. Actually this is a very loose description of the process; rather do we work simultaneously with the relative and absolute contours which are mutually adjusted to ensure the best over-all consistency with the observations. It is sometimes argued that where observa-



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178
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182
184

FIG. 1—MEAN THICKNESS IN JANUARY 1948 OF THE 1000 TO 500-MB. LAYER IN HUNDREDS OF FEET

tions are numerous and the network adequate it is a waste of time, in a busy office, to bother with thickness charts when the total contours can be constructed directly with equal accuracy. I have no quarrel whatever with this argument but even if the only object is to construct contour charts it must be pointed out that in a forecast service it is necessary to prepare charts for which, in the nature of the case, there are no observations whatever: I allude to the predicted charts or " prontours ". In this connexion the closeness of the observational network is almost an irrelevancy. It may of course be further agued that prediction techniques can be developed without attention to thicknesses but here I would join issue. The variation in the thickness pattern is solely dependent on temperature variations and these variations are restricted by physical processes: advection, adiabatic changes and non-adiabatic processes (radiation, conduction and turbulence), including the phase changes of water under one or other heading. The forecast thickness pattern must be consistent with the possible changes of temperature by these processes and it seems to me most desirable to keep this aspect of things in the forefront. Theoretical considerations set limits to the temperature changes which are possible by the several processes, and research in these matters is going on in this country and elsewhere. It is possible to translate the theoretical results into terms of thickness changes and so ensure that the three-dimensional prediction, as represented by the selected prontour charts, is hydrostatically reasonable. By this means, at least one property of the atmosphere is taken care of in the forecasts.

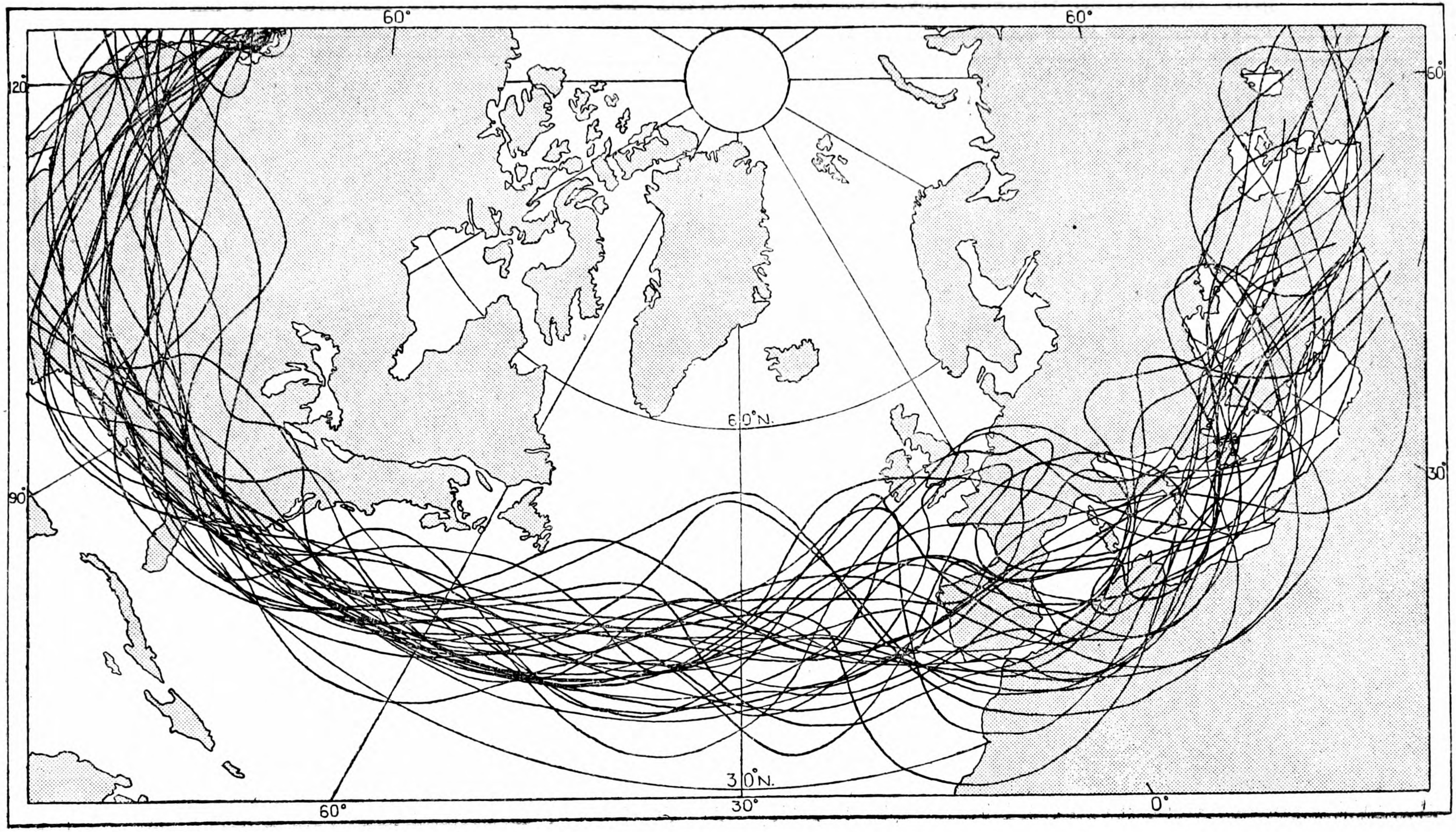
Not only may the problem of thickness changes be approached theoretically but it may also be attacked empirically using for the purpose the technique which is developed for forecasting. I will indicate what I have in mind by illustrations from the 1000 to 500-mb. thicknesses. In Fig. 1 are given the mean thickness lines for the month of January 1948. Such charts are now available for the last eighteen months and may be used by the routine forecaster in judging to what extent the current temperature field is abnormal. Another form of representation is given in Figs. 2, 3 and 4 which show on one map all the positions taken up by a selected thickness line on the morning charts of one month. Similar diagrams have been drawn for four selected lines for each of the eighteen months and will continue to be prepared as a routine for some time to come. The grossly asymmetric run of the lines with reference to the pole is very graphically displayed as well as the northern and southern limits of their displacements. The charts illustrate no new principles of synoptic climatology, the fact that cold outbreaks sweep well south over the American continent but are modified by the warm sea over the Atlantic is common knowledge, but the charts do show the fact in a graphic form and in terms of the upper-air analyst's parameters. Months and years differ but the essential climatic tendencies remain and it is my hope to present the results in a form which can be of real practical assistance to the routine forecaster, enabling him to predict the movement of each thickness line with allowance for the geographical areas, the season of the year and the synoptic situation even though he may not be able to allow quantitatively for radiation, conduction, convection, subsidence, etc., as distinct physical processes. What the relative importance of these processes is I cannot say definitely; it must vary of course with circumstances, but I think the available theory and synoptic evidence point to non-adiabatic processes being regularly as important as advective and adiabatic changes. It is sometimes suggested that for short periods of time the non-adiabatic processes can be neglected. This may be true when exceptionally large changes are taking place as in the vicinity of a moving front or depression but, in the area covered by a forecast weather map, such special regions have but limited importance. I cannot believe that the southern limit of the thickness lines, such as is shown in Fig. 2, is invariably or even normally due to the subsidence of southward moving cold air; nor do I believe that the northern limit of warm air is always due to the occluding process. The atmospheric changes are, I believe, even from the daily forecasting standpoint, not even approximately adiabatic, a fact which, if it is true, makes quantitative forecasting, solely on the basis of the equations of motion and present conditions, an impossibility. One may rather visualise a non-adiabatic tendency for an abnormal thermal pattern to relax towards the norm, a conception which could have great importance in forecasting and which could well be incorporated in a thickness technique but only indirectly in a total-contour technique.

But I wish to emphasise that I do not advocate the thickness technique merely as an aid in ensuring hydrostatic consistency in the forecasting of contour charts. It is also an end in itself in that it affords a thermal picture more graphic than a system of isotherms at various levels. We see at a glance where the air is cold or warm, the positions of the cold or warm tongues or pools and where the gradients and curvatures are large or small. If one likes to think in terms of solenoidal concentration in the vertical section the thickness chart gives this precisely. I do not know whether there are still any meteorologists who think that the troposphere is divided into quasi-uniform air masses separated by a polar front in which are concentrated, within a zone of a few hundred miles, the major temperature differences. If so he will find it something of a strain to reconcile his view with synoptic experience of thickness charts. On the hemispherical scale, fronts (unless one multiplies them out of recognition) seem often to appear as interesting local features holding within their grasp but a small bundle of solenoids, significant, but not dominant in the general development problem. As all fundamental theory places temperature in a prominent place it seems unwarranted that its field representation should take second place to isobars or contours; thickness patterns go a long way to redress the balance.

I have still a further plea. In a paper, recently published, I have given theoretical arguments for linking the dynamical development of the circulation systems with the thickness patterns. The value of the results, to me, does not lie in the degree of reliability of the detailed theory but in the encouragement it affords to trying to develop practical empirical rules relating movement and development with thickness and contour or pressure patterns, and in a form suited to routine forecasting. I cannot go into this subject now but I may say that we are directing our attention to thickness gradients and curvatures and especially to the variations of these quantities. Theory suggests that the third derivatives of temperature are all-important.

My advocacy of thickness patterns is thus based on several arguments which I may summarise as follows:—

(*a*) they are a safeguard in contour analysis, and especially in contour forecasting, against the introduction of hydrostatic inconsistencies;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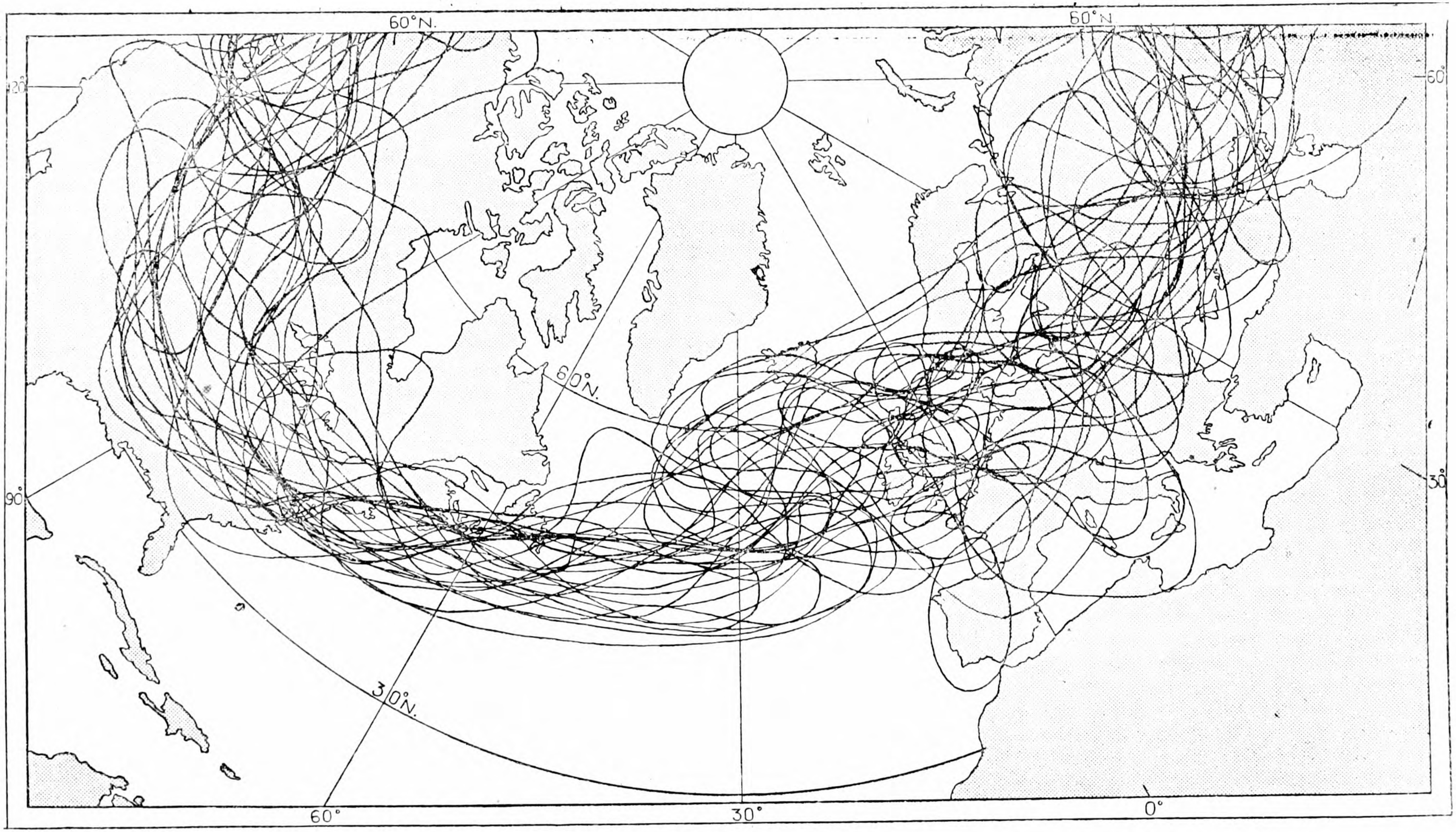
0°

FIG. 2—COMPOSITE CHART OF 18,000-FT. THICKNESS LINE FOR EACH MORNING OF JANUARY 1948


60°N.
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60°
90°
30°
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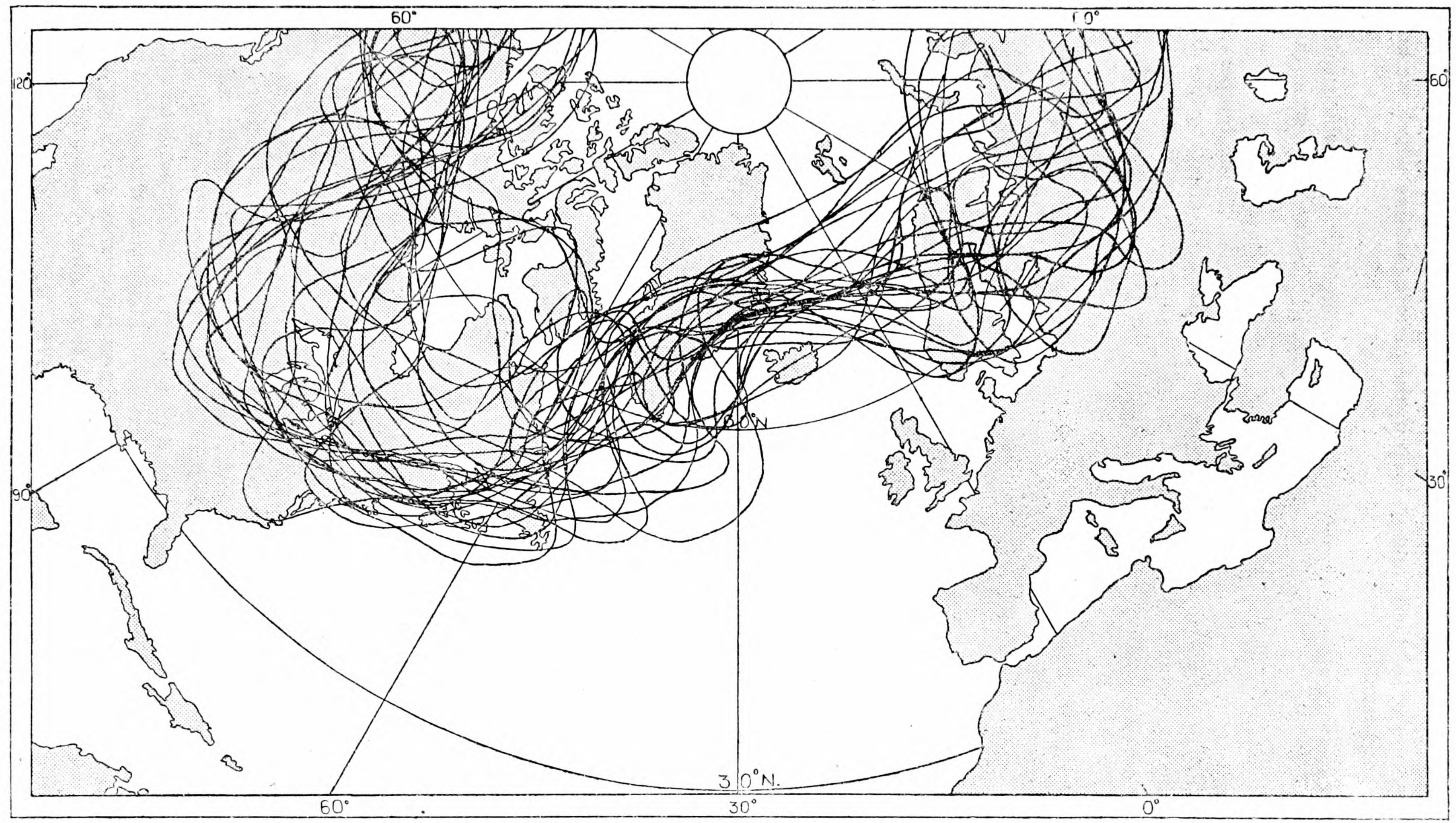
30°
0°

FIG. 3—COMPOSITE CHART OF 17,400-FT. THICKNESS LINE FOR EACH MORNING OF JANUARY 1948


60°
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120°
60°
90°
30°
30°N
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30°
0°

FIG. 4—COMPOSITE CHART OF 16,800-FT. THICKNESS LINE FOR EACH MORNING OF JANUARY 1948

(*b*) they give a good general picture of the temperature field and an accurate representation of solenoids and so keep in the picture features which we know must be important;

(*c*) they aid in air-mass and frontal analysis often indicating which surface fronts are of major and which of minor significance in the large-scale three-dimensional circulation pattern;

(*d*) in a sequence of charts they indicate the changes in the temperature field and give prominence to non-advective processes, so affording the basis for a technique which will be *thermodynamically* reasonable, air-mass modifications, major frontogenesis and frontolysis and the occluding process are also indicated;

(*e*) they afford a promising basis for progress in dynamical analysis and the forecasting of development in the pressure-circulation patterns.

I was once publicly accused of fanaticism about thickness charts. Let me then admit that I do not believe that synoptic meteorology has yet provided itself with a set of isopleths which can be of so much value to the forecaster as a set of well chosen thickness lines; but, as no one likes to be called a fanatic, I will concede, if reluctantly, that there is still something to be said for the mean-sea-level isobars.

It will be said that the system is inadequate; we must have total contours for winds and dynamical analysis, isotherms for temperature forecasting, charts of the tropopause topography, a multitude of tephigrams for stability studies, humidity charts, cross-section diagrams, frontal-surface topographies, hodographs, isentropic charts, constant-vorticity trajectories, and special charts for the study of dynamical instability. There is no end to the aids. But there is an end to the powers of the human brain. Until we develop totally new techniques, with or without electronic brains, we must continue with the system which demands that the forecaster shall be in a position to make a mental model of the synoptic situation. A limited technique, albeit incomplete, may if efficiently used be more successful than an over-elaboration however theoretically admirable.

Sometimes one may hear it provocatively argued that all the modern ideas of meteorology with their impressive techniques have made little impact on the accuracy of the 24-hr. or 48-hr. forecasts. There are competent forecasters ready to claim that they can do just as good work with their surface charts carefully analysed and calmly considered. This is an over-statement, but it is not irrelevant to recall that the technique of frontal analysis, introduced some thirty years ago, won over its adherents with remarkable speed. This was not because the Norwegian model of depressions was theoretically satisfying, indeed the theoretical basis was rather strikingly inadequate, but because it placed in the hands of the forecaster a tool which he could use, one adapted to his particular needs—so much so, that some analysts now force the atmosphere to suit their tool. I regard the thickness patterns as providing another general-purpose tool suited to the work of a forecasting office and I believe it is possible to develop a workmanlike technique.

R. C. SUTCLIFFE

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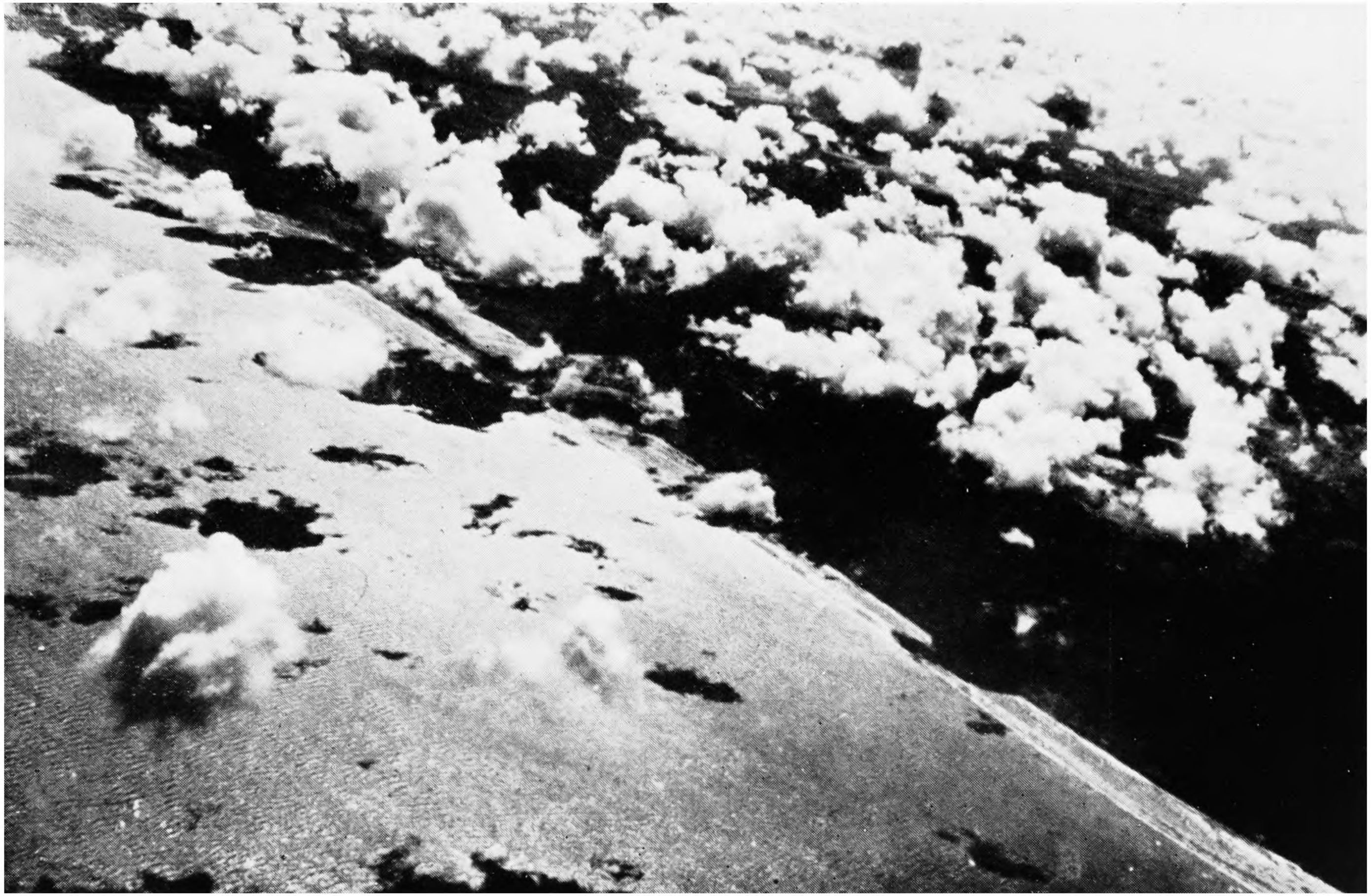

Photograph by R.A.F.

CLOUD SHADOWS ON SEA AND LAND

Cumulus cloud over the French coast, looking south-east from 18,000 ft. over 51°00′N. 1°50′E. at 1102, June 27, 1944.

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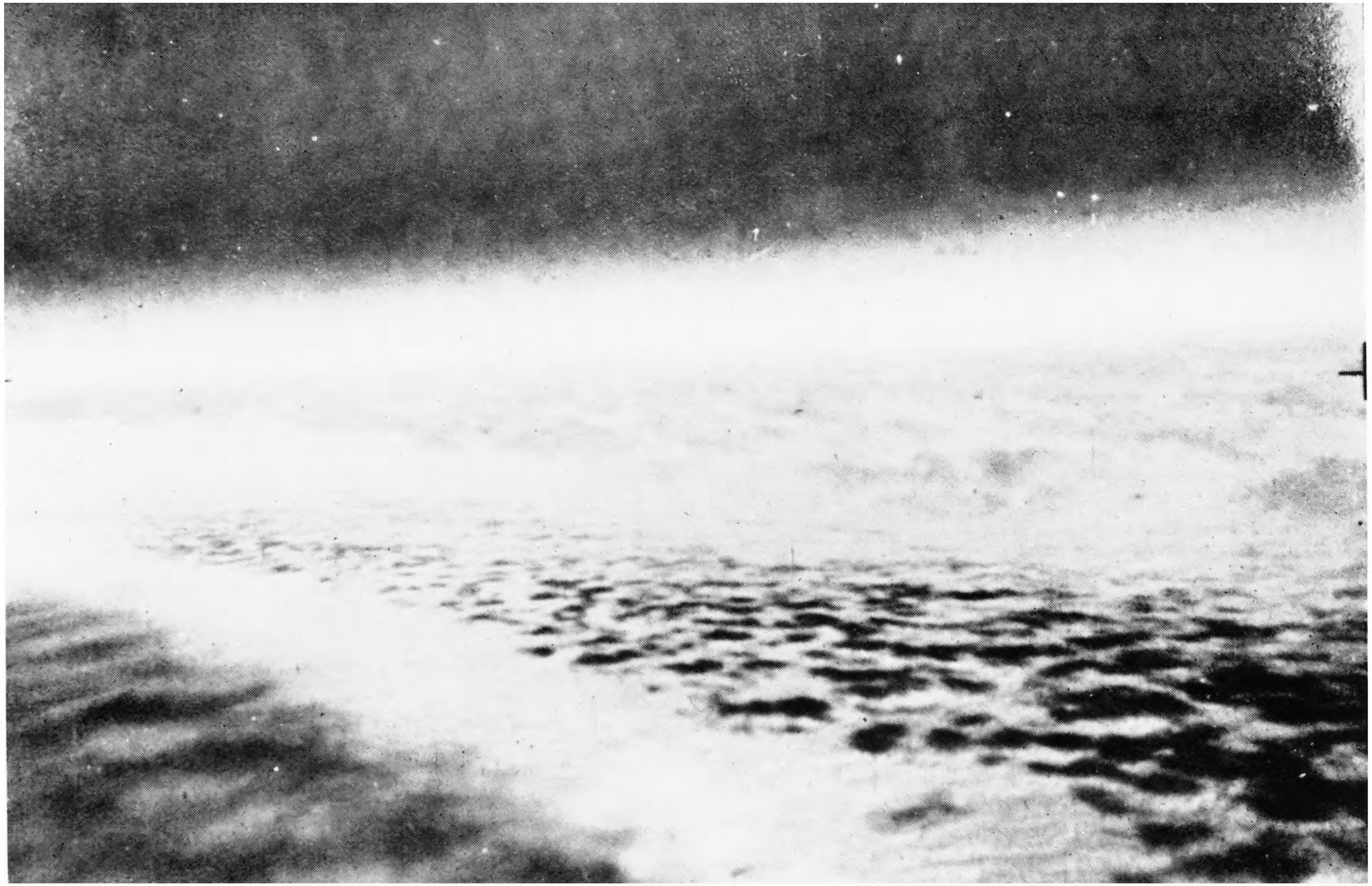


Photograph by R.A.F.

CLOUD SHADOWS ON CLOUD

A broken layer of altocumulus above a layer of stratocumulus. Photograph looking north-east from 28,000 ft. over 52°44′N. 8°00′E. at 1440, October 27, 1944.

SEVERE STORMS OF JULY 2-4, 1946

During the afternoon of July 2 and the night of July 3–4, 1946 many parts of England, east of a line from the Solent to the Humber, suffered severe damage by rain, hail and wind associated with thunderstorms of tropical intensity. Isolated outbreaks of a similar character occur in most years but this particular series was remarkable for the size of the area involved, as well as for the damage caused.

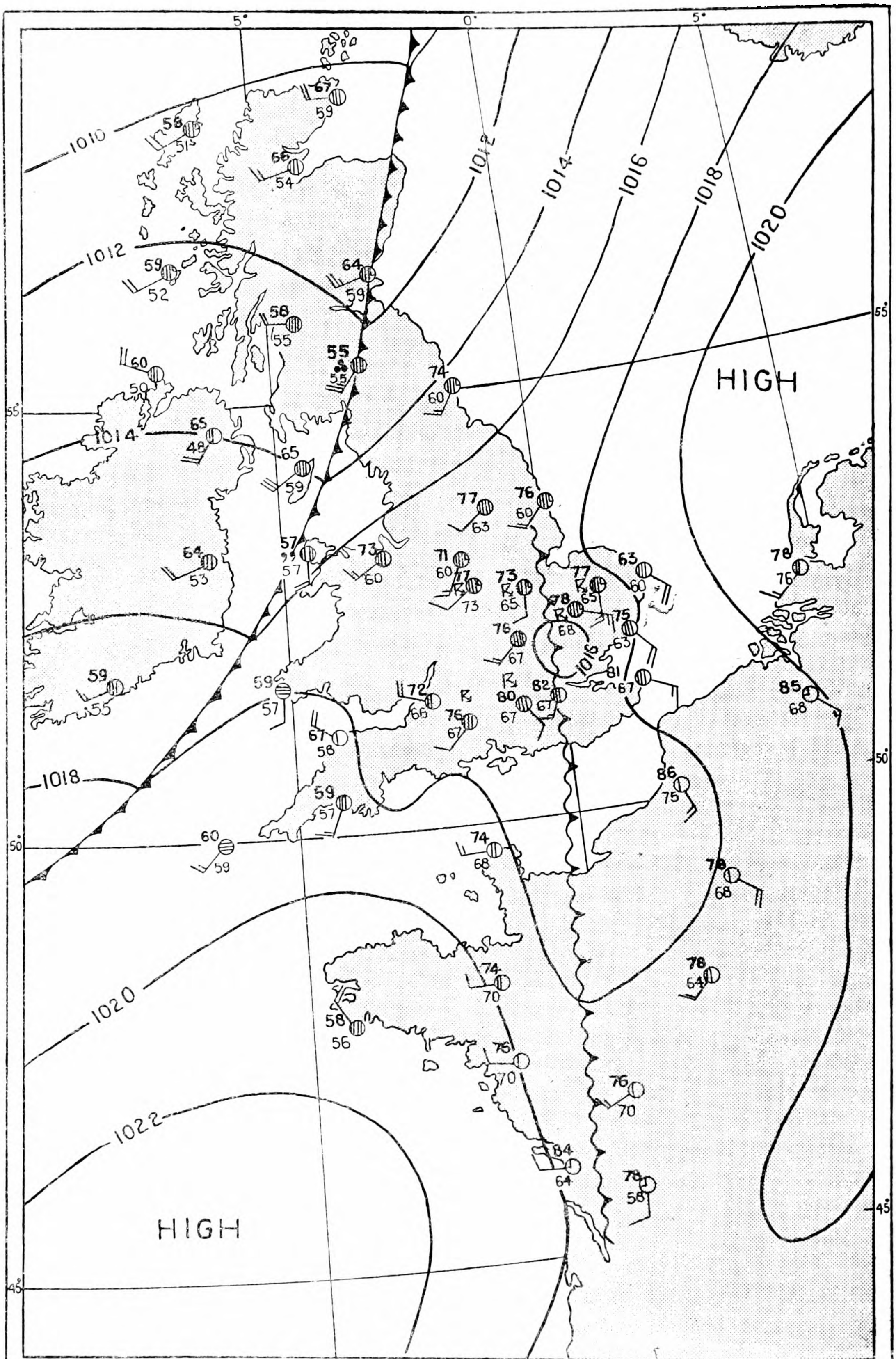
The area principally affected by the storms of July 2 covered west Suffolk and the adjoining parts of Norfolk and Cambridgeshire. A second area over Lincolnshire appears to have been affected more uniformly on a somewhat lower scale. In both areas the period of maximum activity was between 1200 and 1500 G.M.T., though storms continued over a wide area well into the evening.

On the 3rd, thunderstorms broke out over a wide area of eastern England and north France in the late evening, with maximum intensity, as regards this country, in the Farnham-Basingstoke district around midnight, and in west Suffolk and Norfolk 1 to 2 hours later. Very high lightning frequencies were reported, mostly in the clouds, indicating that these were typically high-level storms.

Synoptic situation.—At 0600 G.M.T. on July 1 a depression of moderate intensity with a wide warm sector from Ireland to the Azores was centred about 55°N. 25°W. and moving slowly north-east. An anticyclone over France was giving way to a developing instability trough over the south-eastern half of the Bay of Biscay. Thunderstorms broke out during the day in the neighbourhood of the instability trough, on which a separate circulation had formed, by evening, centred in the Bay of Biscay. By 0600 on July 2 the Biscay low was centred near the Channel Isles and moving east-north-east. The circulation remained feeble but can be followed on the synoptic charts via the Straits of Dover to Holland and Hanover by 0600 on the 3rd. Isolated thunderstorms probably associated with it were reported from Kent at 0900 G.M.T.

The severe storms which occurred over East Anglia and Lincolnshire appear to have been a separate development in the slack gradient to the north of the instability low. Rain reported in the Bristol area at 0900 G.M.T. spread rapidly north-east, increasing in intensity, and by 1200 heavy thunderstorms were in progress over much of Cambridgeshire, Huntingdonshire, west Suffolk, south-west Norfolk and Lincolnshire. During the afternoon and early evening (see Figs. 1 and 2) practically the whole of eastern England between the Thames and the Humber became affected to some extent. Separate surface circulations with strong local winds formed over the main storm areas, but in view of the generally south-westerly gradient aloft there is nothing to suggest any direct connexion between the mid-morning storms of Kent and the Dover Straits and the later storms of East Anglia.

During the night of the 2nd–3rd the cold front of the Atlantic depression moved eastwards across the northern North Sea, and by 0600 extended from north-east England to a wave west of Brittany. The frontogenetic nature of the storms of the 2nd was clearly indicated by a cold front from just west of Holland to the western Pyrenees, with a wave over Normandy on which a circulation developed during the day with a movement corresponding to the upper air current. The storms of the night of the 3rd–4th were widespread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HIGH
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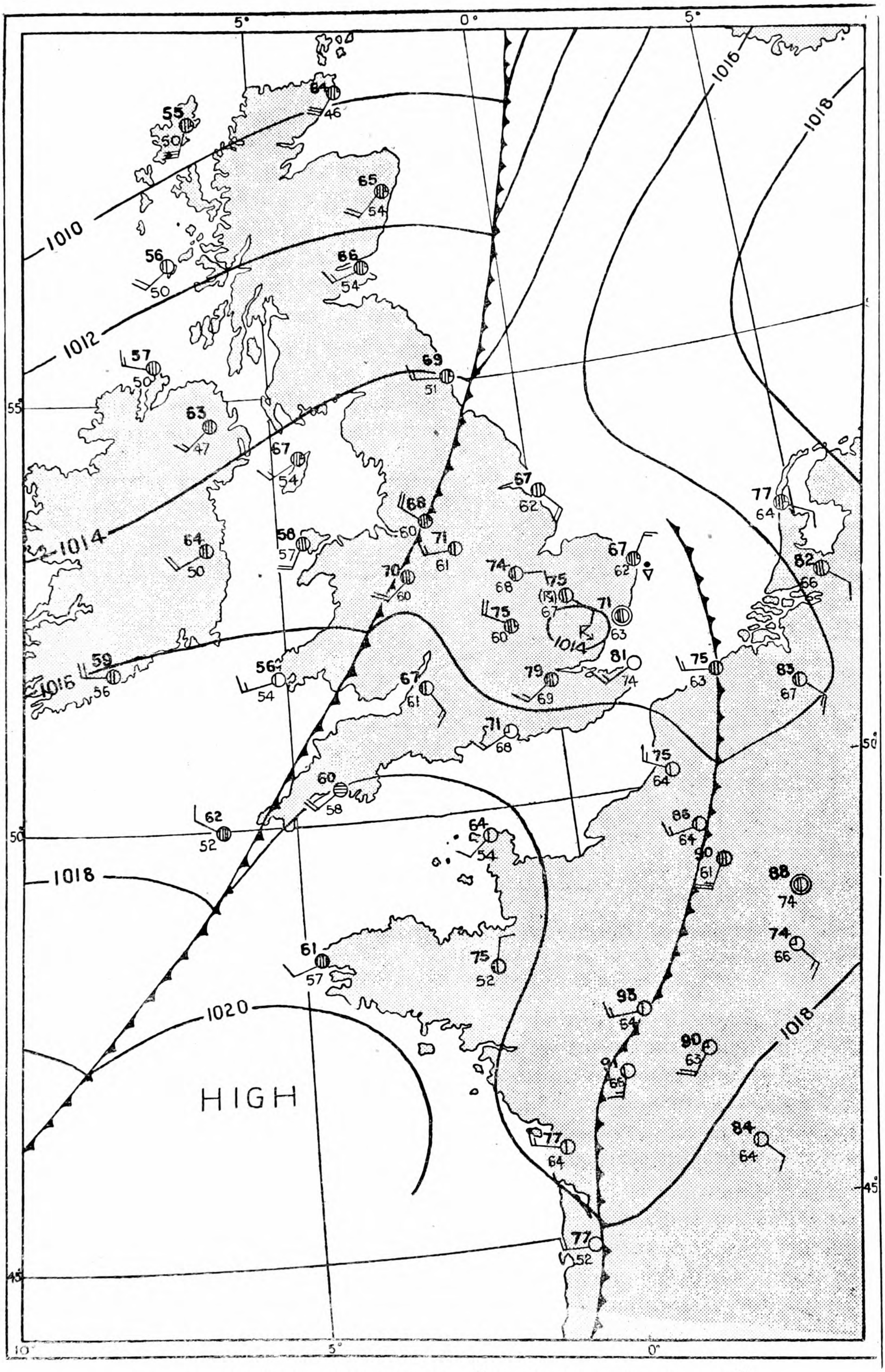
55°
55°
50°
50°
45°
45°
5°
0°

FIG. I—SYNOPTIC CHART FOR 1200 G.M.T., JULY 2, 1946
Bold figures represent dry-bulb temperatures, thin figures represent dew-point temperatures; other symbols have their usual meaning.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52

FIG. 2—SYNOPTIC CHART FOR 1800 G.M.T., JULY 2, 1946

Bold figures represent dry-bulb temperatures, thin figures represent dew-point temperatures; other symbols have their usual meaning.

both in this country and on the nearby continent and were most severe on the warm front of the depression.

Upper air conditions, July 2-3.—*Temperature.*—Larkhill (0000) and Downham Market (0600) on the 2nd showed strong similarities as regards temperature and moisture content, with freezing level 650 mb. (12,000 ft.) and a lapse rate unstable for saturated air above 800 mb. (7,000 ft.), but the air was not saturated at 450 mb. (20,000 ft.).

Between 0000 and 0600 at Larkhill, advection of warmer and drier air took place above 450 mb. (20,000 ft.). This had been foreshadowed by the veer and increase in winds above 500 mb. (18,000 ft.) on the midnight ascent.

The midday ascent at Downham Market was made in rain after thunderstorms had broken out in the district and convection had already carried much moisture into the upper layers. Relative humidity was over 80 per cent. at nearly all levels and the lapse rate unstable for saturated air up to at least 500 mb. (18,000 ft.), with slightly stable saturated air above. The mean lapse rate throughout the ascent to 350 mb. (30,000 ft.) was very nearly along the 65°F. wet-bulb potential-temperature curve. By evening, after the cessation of the main storm activity, the lapse rate had settled down to slightly more than the saturation value and the fall in wet-bulb potential temperatures indicated a real air-mass difference associated with frontogenesis.

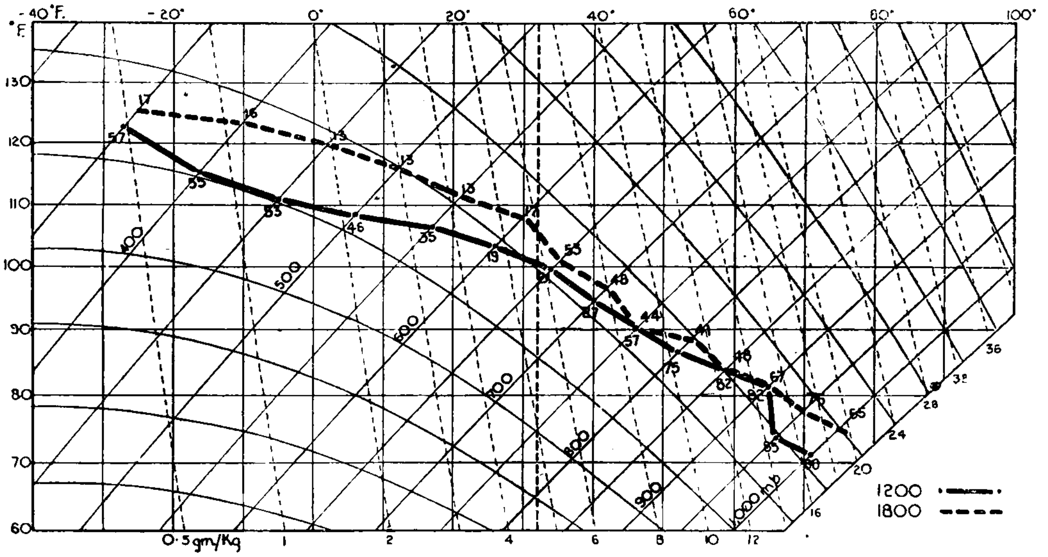


FIG. 3—TEPHIGRAM OF UPPER AIR ASCENTS OVER LARKHILL, JULY 2, 1946
The figures are the values of relative humidity calculated with respect to water above freezing point, and with respect to ice below freezing point.

On the morning of July 3 the 0600 Downham Market ascent again showed instability for saturated air above 800 mb. (7,000 ft.), and as the relative humidity was over 80 per cent. up to 500 mb. (18,000 ft.), conditions were highly favourable for developments of intensity comparable to the previous day. The tendency was accentuated by advection from France of very warm air in the lower levels.

Figs. 3 and 4 illustrate the upper air temperatures at Larkhill and Downham Market at the time of maximum activity on the 2nd.

Tropopause, July 1–3.—The height of the tropopause throughout the period was in the region of 39,000 ft., with some irregular features:—

(i) A fall to 37,000–37,500 ft. on the 1st.
(ii) A rise to about 41,500 ft. on the 2nd.
(iii) A rise to 44,500 ft. at Larkhill on the midnight ascent of the 2nd–3rd, not shown at Downham Market.

Upper winds and electrical disturbance.—July 2.—Before the storms, winds were fairly uniform at 200° 20 kt. up to 700 mb. (10,000 ft.), veering and increasing with height to 270–290° 35–40 kt. at the tropopause. During the storm period winds in the higher levels backed to 240°, increasing to 60 kt., subsequently becoming 210–230° 30–40 kt.

Although the Downham Market midday ascent was made in rain and one of the most violent storms was then in progress 15 miles to the south-east, there was no indication of local winds associated with the storm centre.

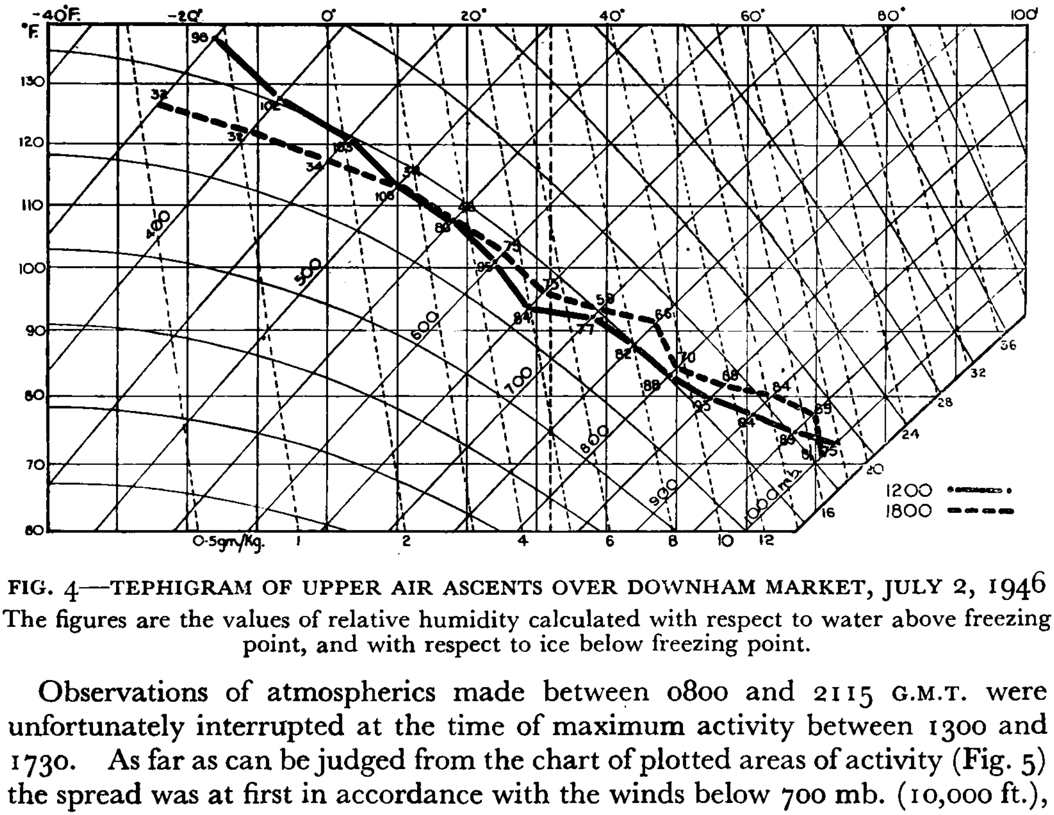


FIG. 4—TEPHIGRAM OF UPPER AIR ASCENTS OVER DOWNHAM MARKET, JULY 2, 1946
The figures are the values of relative humidity calculated with respect to water above freezing point, and with respect to ice below freezing point.

Observations of atmospherics made between 0800 and 2115 G.M.T. were unfortunately interrupted at the time of maximum activity between 1300 and 1730. As far as can be judged from the chart of plotted areas of activity (Fig. 5) the spread was at first in accordance with the winds below 700 mb. (10,000 ft.), but subsequently became more in agreement with the winds at higher levels. The drift of the storms in Suffolk agreed substantially with the low-level winds of 200° 15–20 kt., while over Lincolnshire the direction of movement seems to have been in agreement with the winds between 10,000 and 20,000 ft., i.e., about 250° 20–25 kt. The explanation may be that the former were essentially low-level and the latter high-level storms.

July 3.—Winds were generally light south-easterly up to 850 mb. (5,000 ft.) Above this level the direction became steady at 200–220°, speed increasing gradually with height to 50–60 kt. at the tropopause. No observations of atmospherics are available for the storms of the night of the 3rd–4th.

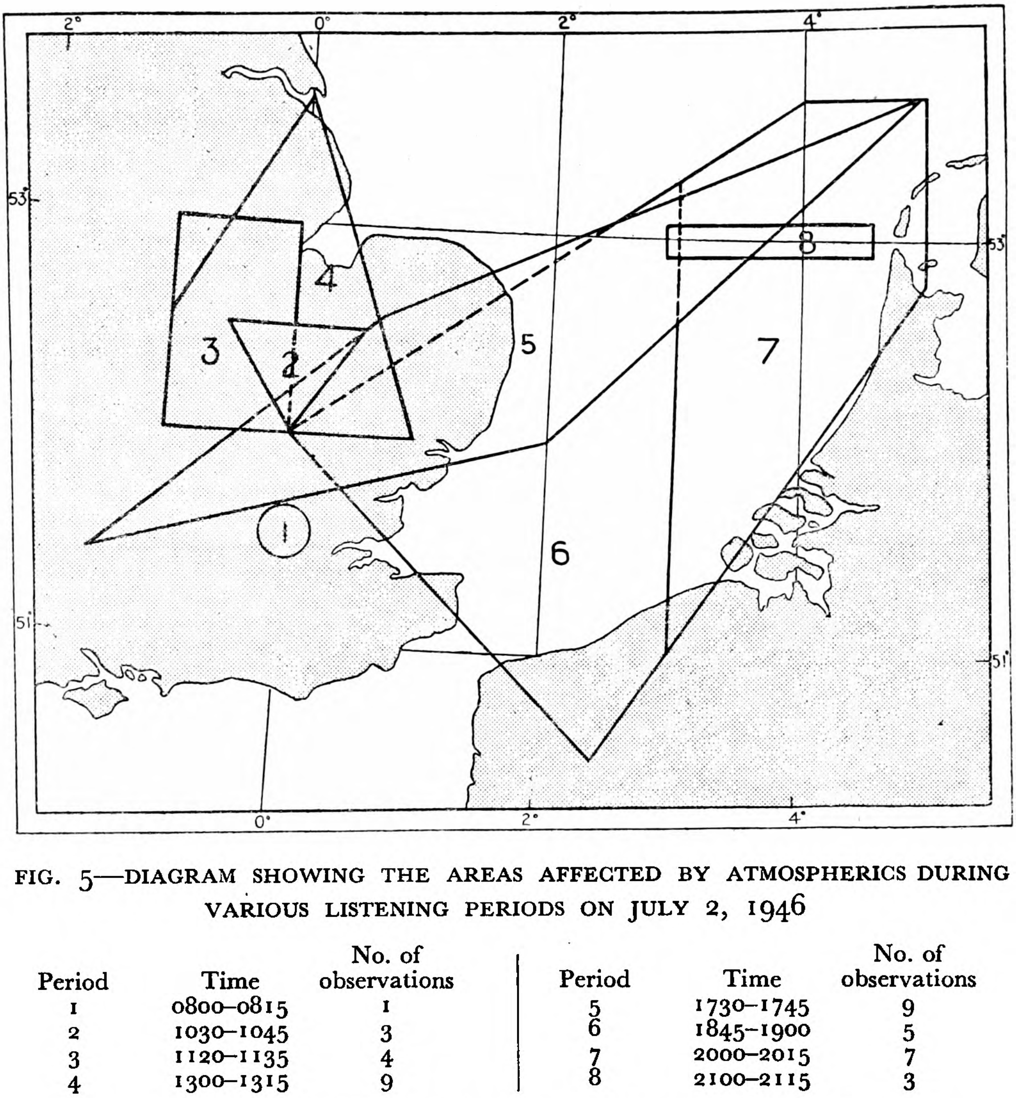


FIG. 5—DIAGRAM SHOWING THE AREAS AFFECTED BY ATMOSPHERICS DURING VARIOUS LISTENING PERIODS ON JULY 2, 1946

Period	Time	No. of observations	Period	Time	No. of observations
1	0800–0815	1	5	1730–1745	9
2	1030–1045	3	6	1845–1900	5
3	1120–1135	4	7	2000–2015	7
4	1300–1315	9	8	2100–2115	3

No observations were possible between 1315 and 1730 G.M.T.

Local reports.—The storms received a good deal of publicity at the time, but a number of reports from experienced observers have been received, from which the following will serve to emphasise the exceptional nature of the events described.

July 2.—*Mildenhall, Suffolk.*—There were three distinct storm periods, namely 1200–1230, 1400–1500 and 1700–1800 G.M.T., with a total precipitation of 1·58 in. The most severe damage was caused during the first phase, in a mile-wide belt from the Cambridgeshire border near Soham to south-west Norfolk between Brandon and Thetford. Two observers mention funnel clouds at the time. In some parts whole fields of growing crops were so completely destroyed as to be unrecognisable. Numbers of poultry were killed or blinded by the hail, which accumulated to a depth of 15 in. in drifts and lay still unmelted next morning, when it was seen being shovelled out of a tradesman's yard. At Mildenhall the recorded wind reached 26 kt. for a quarter of an hour, with a maximum gust of 41 kt.

Tuddenham, Suffolk.—There were two major storms, at 1130–1230 and 1430–1530 G.M.T., the latter being the more severe. This storm passed directly over the airfield and the wind, which reached 26 kt. at times, completely boxed the compass. Very heavy hail measuring up to 1 in. in diameter and torrential rain fell, causing local flooding and interrupting telephone and teleprinter communications.

Marlingford Hall, Norfolk.—There was a brief but intense storm lasting only 5 min. at 1400 G.M.T.; 0·64 in. of precipitation fell in the form of hailstones which measured up to 1¼ in. in diameter half an hour after the storm; 168 panes of glass were broken in one greenhouse.

Bury St. Edmunds, Suffolk.—At Westley 2·36 in. of hail and ice fell, causing much damage to crops.

Hawley Green, Stowmarket.—Precipitation exceeded 2 in. It is interesting to note that 10 to 15 miles to the south of Bury St. Edmunds and Stowmarket precipitation was negligible or absent.

Cromer, Sprowston and Santon Downham.—Here also, very large hail, ¾–1 in. in diameter, and serious crop damage was reported.

Coningsby, Lincs.—Between 1300 and 1400 G.M.T. a most severe storm occurred, accompanied by rain of tropical intensity with wind of gale force estimated up to 70–80 kt. in squalls. An Anson aircraft was blown a distance of 200 yd. from its chocks, and a lorry was blown against a Lancaster. A corrugated-iron hut was blown a distance of 100 yd., smashing 4-in. reinforced posts on the way.

Night of July 3-4.—*Farnham, Surrey.*—There was a violent storm with almost continuous lightning and heavy hail between 2300 and 0100 G.M.T. For about 15 min. the wind reached gale force, flattening hop-gardens and breaking branches from many fruit trees. Hail broke thousands of panes of glass and many roofing tiles. Total fall: 1·3 in. Similar descriptions were received from Churt and Rowledge.

Bramley, Basingstoke.—During a thunderstorm which occurred from 2345–0015 G.M.T. a thatched house in a nearby village was fired by lightning; 0·77 in. of rain was measured.

Margate.—2·16 in. of rain and hail fell during the night.

West Suffolk and Norfolk experienced heavy and prolonged storms, mainly of rain. At Westley (Bury St. Edmunds) 2·75 in. fell, making 5·11 in. within 2 days, causing severe local flooding with water up to bedroom level in the lower part of the town.

Mildenhall.—The thunderstorm between 0100 and 0200 G.M.T. was accompanied by only light precipitation but was followed by variable, mainly moderate continuous rain until 0900 G.M.T., totalling 0·44 in.

Marlingford Hall, Norfolk.—There was a severe storm lasting all night. 1·7 in. of rain were recorded.

Characteristics of hailstones.—As would be expected, descriptions of the form taken by the hail vary considerably. Most commonly they are described as roughly spherical, with some degree of flattening. At Farnham, Surrey, the lesser diameter was only half the greater (see Fig. 6), but in all other cases departure from the spherical appears to have been relatively slight, except where

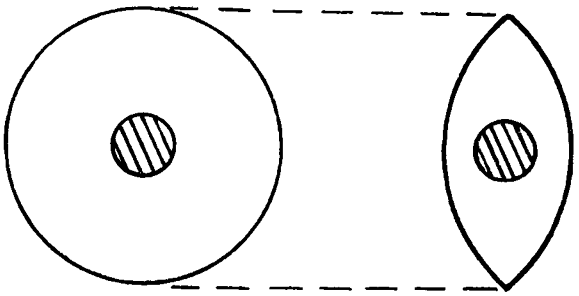


FIG. 6—ACTUAL SIZE AND SHAPE OF THE HAILSTONES OBSERVED AT FARNHAM, SURREY

There is a soft opaque core in the centre surrounded by solid ice; some extra-large stones were rough and of a rectangular crystalline formation.

stones seem to have been fragments of larger spherical or ovoid originals. The "jagged lumps of ice" referred to in some Press reports are not confirmed by any reliable observers, but the explanation may be that where hail lay thickly many smaller stones coalesced.

In general the largest hailstones were about 1¼ in. in diameter but some, which fell as irregular pyramids, may have been of greater size before they broke, possibly in mid air.

The structure in most cases consisted of an opaque nucleus surrounded by clear ice, but at Barton Mills, Suffolk, the stones are described as having alternate layers of clear and opaque ice, while at nearby Tuddenham, during the same storm, spherical stones of clear ice ¾–1 in. in diameter were observed.

F. W. JUDE

METEOROLOGICAL RESEARCH COMMITTEE

The first meeting of the Instruments Sub-Committee was held on April 29. This first meeting of the Sub-Committee was devoted to reviewing the various instrumental problems which are being investigated in the Meteorological Office.

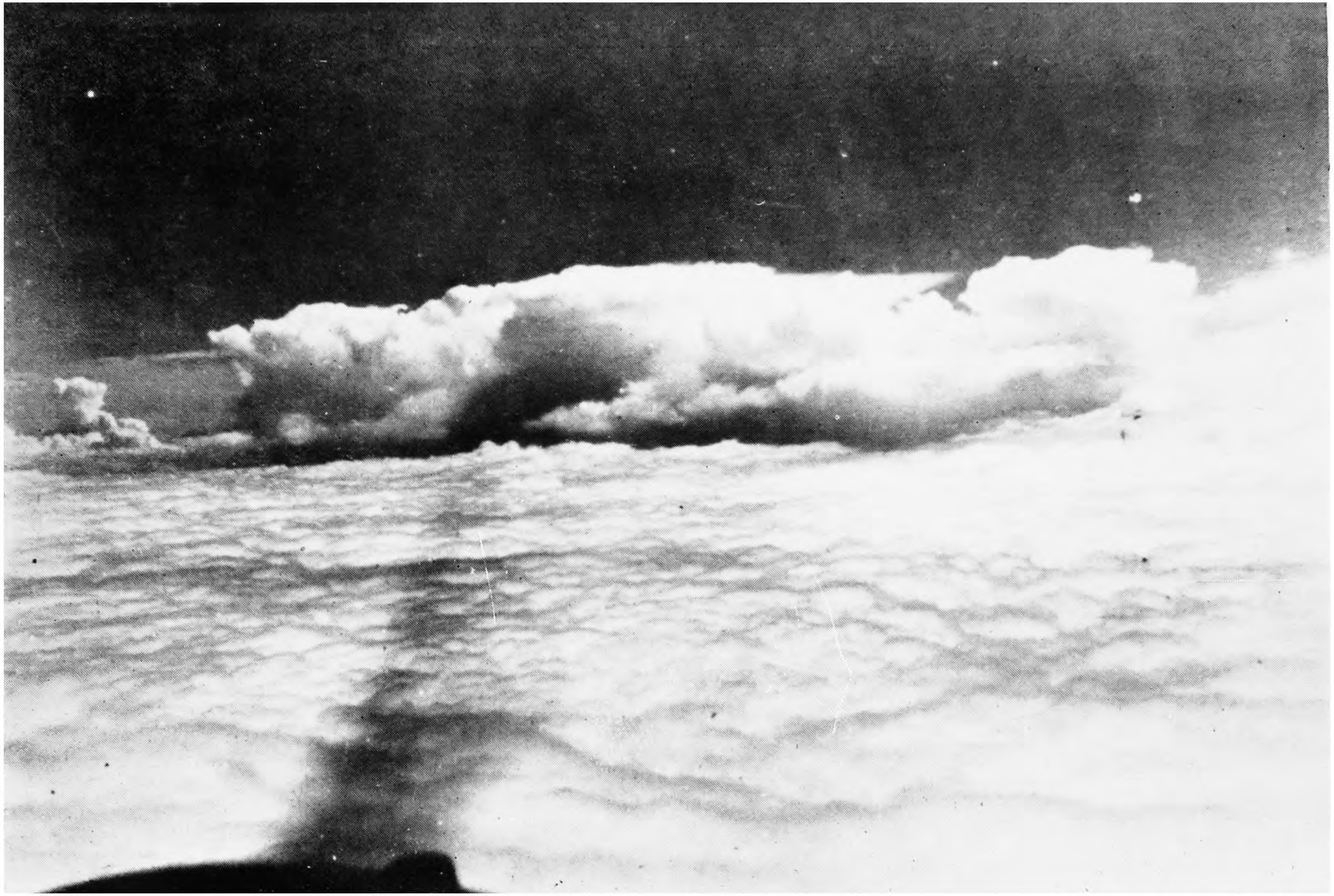
The first meeting of the Synoptic and Dynamical Sub-Committee was held on May 6. The lines along which the various problems of synoptic and dynamical meteorology in the Committee's programme should be tackled were considered.

The question whether the saturated adiabatic and the humidity mixing-ratio lines on the tephigram should be altered to conform with condensation of water vapour to liquid water, instead of sublimation to ice, at temperatures below 0°C. was discussed but it was decided that present knowledge of the physical processes of condensation and sublimation at sub-freezing temperatures is inadequate to justify a change.

A paper by J. K. Bannon dealing quantitatively with the error involved in the use of the gradient wind as an approximation to the true wind in disturbed conditions was also discussed.

The second meeting of the Physical Sub-Committee was held at the Clarendon Laboratory on May 12. During the morning the Sub-Committee were able to inspect the work in progress, on condensation and sublimation of water vapour, under the supervision of Prof. Dobson. In the afternoon the lines along which this work should be developed were discussed.

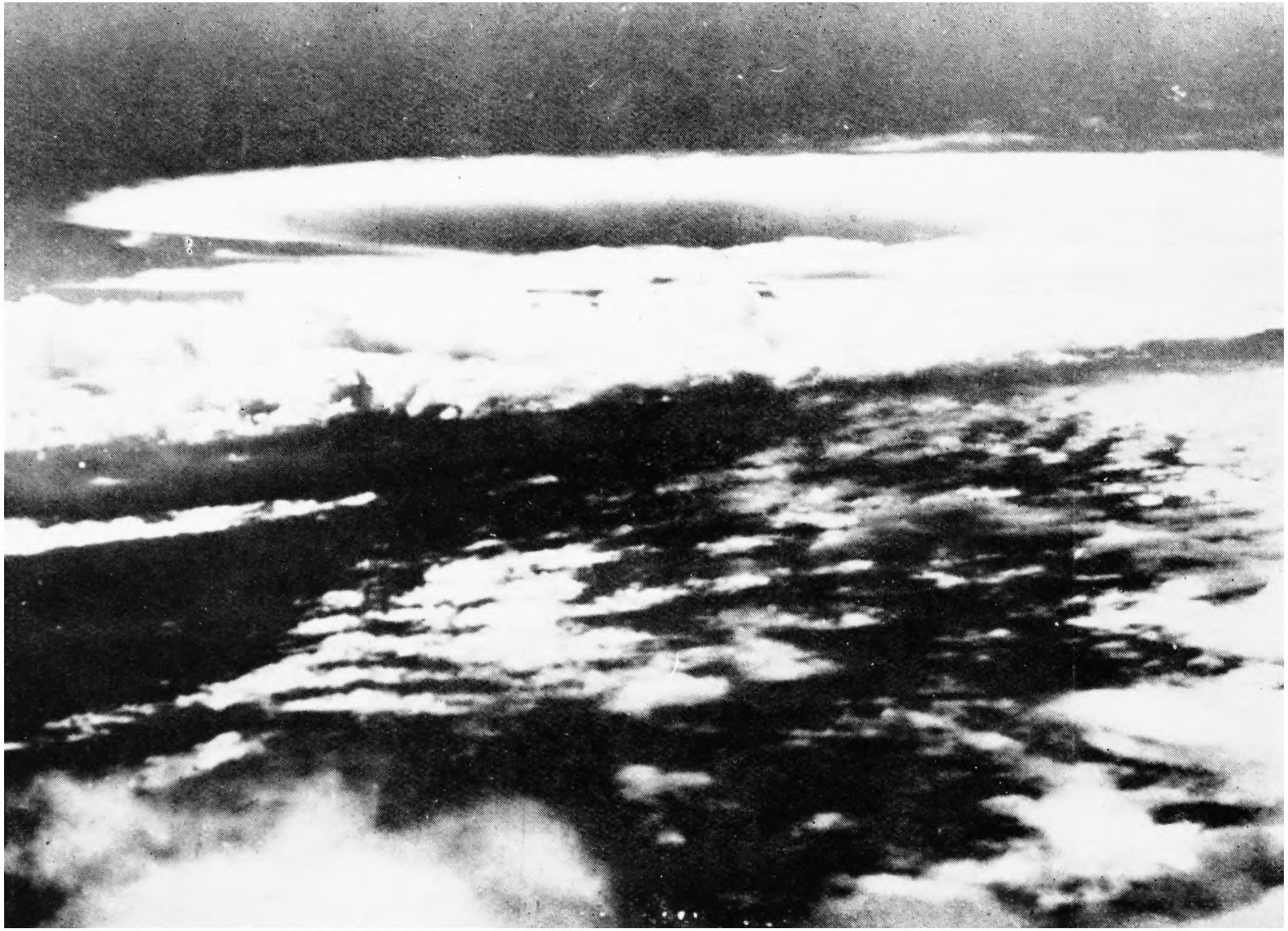
[*To face page* 160



Photograph by R.A.F.

CUMULONIMBUS ANVILS OVER SUFFOLK

There were thunderstorms in the area at about the same time. Photograph taken looking south from 15,000 ft. over 52°40′N. 0°45′E. at 1425, June 1, 1944.



Photograph by R.A.F.

LARGE CUMULONIMBUS ANVIL IN THE BAY OF BISCAY

Photograph taken looking south-west at 1306, August 8, 1944, from 16,000 ft. over 46°20′N. 2°30′W.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society, held at 49 Cromwell Road, on May 19, 1948, Prof. G. M. B. Dobson, President, in the Chair, the following papers were read:—

J. S. Sawyer—The structure of the intertropical front over N.W. India during the S.W. monsoon.

Opening this paper, Mr. Sawyer drew attention first to the general circulation over north-west India during August. The mean pressure and surface wind flow for this month showed a general trough of low pressure over southern Iran to Afghanistan and north-west India, with an extension down the Ganges valley. The inflow of surface winds into this region could be divided by a line, along the southern coast of Arabia and the north-west frontier of India, between those from the continent and those from the Indian Ocean; this line is the normal surface position of the intertropical front (I.T.F.). Similarly mean upper-wind maps showed the normal position of the I.T.F. to be 400 miles further south at 3 Km. but a shorter distance further south at 6 Km.

Consequently, the I.T.F. might consist of a front sloping one way in the lower levels (up to 10,000 ft.) and sloping the opposite way in the higher levels. This fits in with the known facts that, because of the steeper lapse rate and higher surface temperatures of the continental air, it would be warmer than monsoon air and therefore tend to overlie it in the lower levels, the reverse occurring in the higher levels.

Mr. Sawyer then proceeded, with the help of 700-mb. and 500-mb. pressure surfaces drawn for each day between August 23 and September 1, 1945, using pilot-balloon wind observations and radio-sonde data from several stations in the area, to work out the structure of the I.T.F. on several days. These were illustrated by several slides, some of maps at different levels on the same day and some of tephigrams of the air masses involved, including two showing the " nose " of continental air sandwiched between monsoon air. Also using information gathered from aircrew flying in monsoon conditions, he drew two schematic cross-sections across the I.T.F. showing the different types of cloud and weather likely to be experienced in the region of the I.T.F.

C. A. Wood—Report on the weather of the Borneo-Celebes region, 1946.

In the absence of Mr. Wood this paper was read by Inst. Lt. Cdr. Thorp. It draws attention to the difficulties of forecasting in tropical regions near the equator where even surface observations are very sparse. " Imagination may run riot over thousands of square miles of unrelieved blankness on the chart; surface wind shows a healthy contempt for the isobars, and land and sea breezes become the decisive factors."

The paper describes the weather conditions at Balikpapan which is just over one degree south of the equator and on the east coast of Borneo, facing the Macassar Strait and the island of Celebes. Both Borneo and Celebes are mountainous and the weather is strongly affected by topography.

A major feature was the formation of what were called disturbance lines, orientated east-north-east to west-south-west drifting from the north (over North Borneo ahead of surges of the Asiatic high) from December to March, from the south in March and April, and during the SE. monsoon from May to October. These disturbance lines could be frontal (associated with fronts from the north or the intertropical front) or orographic or convectional or mixtures of all three, but there was no really conclusive evidence. The paper described the conditions observed both on the surface and in the air in some detail, seven of the disturbance lines very fully.

On the whole, the weather at Balikpapan seemed to consist of thundery rain on most days, temperatures between 70° and 90°F., local surface winds (usually modified by land and sea breezes), good visibility (fog did occur on the rare clear nights after a thunderstorm and locally over marshes and in valleys), much convectional cloud (often cumulonimbus and cumulus pileus) and much altocumulus and altostratus, particularly before and after thunderstorms associated with disturbance lines and/or convection.

Opening the discussion, Sir Charles Normand said that most meteorologists in India had been well acquainted with Mr. Sawyer's construction of the I.T.F., particularly the lower part and Dr. Ramanathan had given some idea based on pilot-balloon ascents. Thanks were due to Mr. Sawyer for completing the scheme in some detail. He would like to stress, however, how much convection spoils the picture in tropical regions: fronts are rarely well marked. One thing that had always puzzled him in India was what happened to the monsoon air over India ? It came in from the south and seemed to vanish over India; it could not escape over the Himalayas, or over Burma since air entered India from that direction, or over Afghanistan since air came in from that direction also.

Dr. Forsdyke, in some general remarks, thought there were two main ways in which disturbance lines could be formed in the tropics; (*a*), as remnants of polar fronts for which there was evidence in disturbance lines ahead of surges from the north mentioned by Mr. Wood, and also in the Carribean and called by the Americans easterly waves; (*b*), originating in the tropics as convergence zones with no contrast of temperature. He emphasised that the movement of fronts formed in convergence zones was difficult to forecast since they did not move continually as fronts do in temperate regions. Dr. Forsdyke illustrated the two types by means of slides and, in particular, showing a complicated method of finding convergence zones by studying the wind field at 2 Km., evaluating, plotting and drawing isopleths of $\partial u/\partial x$ and $\partial v/\partial y$ on two charts and then " gridding " them together to show positive and negative areas of the horizontal divergence $\partial u/\partial x + \partial v/\partial y$.

Cdr. Burgess remarked that it had been found that the westerly winds at certain times in Australia could be traced as originating in the NE. monsoon from Asia; thus some of the disturbance lines could easily be frontal. In the tropics sea breeze and land breeze could be quite large, as much as Beaufort force 4 or 5 vector difference from normal, and could be felt over the sea to a distance of up to 90 miles from the coast. Naval vessels had made an investigation with this result near Ceylon. On occasions convergence between land breeze and sea breeze had been noticed which was quite sufficient to cause cloud and possibly rain.

Mr. de Reuck showed two slides of isentropic cross-section and cloud structure across the I.T.F. He had found that in forecasting, account had to be taken of the amount of penetration of dry air. When a new cold front came from the north over north-west India the lower part of the monsoon air in the I.T.F. disappeared altogether.

Cdr. Hogben repeated the plea of Lt. Cdr. Hines who disliked the term convergence applying to regions where winds merely seemed to flow together. Taking wind strength into account this may not be a region of convergence but only a region of what he would like to call confluence.

Mr. Schove mentioned that when he was in British West Africa he had traced a cold front from the Mediterranean right across the Sahara which fitted in with one of what he called, in his note on equatorial weather, " stability fronts ". Such fronts were very similar to Dr. Forsdyke's easterly waves and seemed to move at 30 m.p.h.

Inst. Lt. Cdr. Thorp, speaking on his own behalf, stressed that in the tropics there was an additional coordinate it was essential to bear in mind: the time of day. It was often reliable to forecast from charts of the previous day since the weather seemed to repeat itself. Land and sea breezes were fundamental and he had noticed a land breeze and monsoon vector fall from 30–35 kt. in the morning to 16 kt. in the afternoon. The confluence resulting from a weak monsoon and sea breeze had often resulted in the very rapid development of cumulonimbus over Trincomali harbour; very heavy thunderstorms used to occur there about 1700–1800 for this reason.

ROYAL GEOGRAPHICAL SOCIETY

On May 3, Prof. Ahlmann, the eminent Swedish glaciologist, lectured to the Royal Geographical Society on " The present climatic fluctuation ".

Prof. Ahlmann, in a brilliant lecture, presented an immense array of facts tending to show the existence since the mid-nineteenth century of a world-wide increase of temperature and decrease of precipitation.

An increase in mean temperature during this period has been found by Manley for England, Labrijn for Holland and Ångström for Sweden. Their concordant curves were projected on the screen. The greatest increase of temperature, however, had taken place in the area between Norway, Spitsbergen, and north-east Greenland in which the mean winter temperatures had increased by over 10°C. since 1912. Evidence of increased heat and reduced rainfall was then advanced from the shrinkage of the Great Salt Lake in Utah, U.S.A., which had occurred in the same time.

In Prof. Ahlmann's view an increase in solar radiation leading to an increase in the general circulation must be responsible for these phenomena.

Prof. Ahlmann then turned to his glaciers, whose state gives an integrated picture of temperature and precipitation changes, and pointed out that in all parts of the world, except Antarctica, about which there is little information, they are rapidly receding. From Alaska, Iceland, Greenland, Scandinavia, the Alps and the high mountains of east Africa the story was one of rapid retreat. In Alaska one large glacier was retreating at the enormous rate of 400 m./year. Comparative photographs of some Norwegian glaciers were projected showing very vividly the shrinkage which had taken place. Many Norwegian glaciers had disappeared altogether. As for the Antarctic the only information he had was from a Norwegian expedition which had just returned and reported to him a diminution in the ice cover at a point on the coast. A companion event was the drying up of tropical lakes which had led to some, in east Africa, practically disappearing in the dry season.

Turning now to the ice of the North Polar Basin, over the area in which Nansen, in the *Fram* in 1893, measured an average thickness of ice of 365 cm., the Russian ice breaker *Sedov* in 1937–40 found only 218 cm. Ships were now able to reach Spitsbergen during 7 months of the year compared with only 3 months in the early part of the century. Russian reports stated that the ice in the Russian Arctic waters shrank by 1 million sq. Km. between 1924 and 1942.

Important biological consequences of the warming of the Arctic were that cod were now to be found up to 73°N. on the Greenland coast, 1,000 Km. further north than in earlier years, that the birch trees of northern Norway which between 1875 and 1915 produced good seed in only two years now produced it almost every year, and that the annual rings of northern trees were getting thicker.

This decrease in the amount of glacier ice might be expected to have an important practical consequence in a gradual rise of sea level. According to Gutenberg the rise at present was only of the order of 1 mm./year. If, however, the Antarctic and Greenland ice caps, which between them contained some 90 per cent. of all the ice in the world, started to shrink at the same rate as the small glaciers the rise in sea level might assume serious proportions. How much the level might rise was not very certain but there was evidence in New Guinea and Australia that the last ice age caused a fall of 90 m. in sea level.

Prof. Ahlmann concluded by pointing out the immense scientific and practical interest of this climatic fluctuation as the first which mankind had the opportunity of following scientifically. In his opinion, the Antarctic held the key position and an expedition to it, to be specially devoted to glaciology, was urgently necessary. In addition to glaciological investigations, radio-sonde observations ought to be made along the meridian from the Antarctic through Graham Land over South and North America and also over Africa.

The full account of Prof. Ahlmann's lecture in the *Geographical Journal* will be eagerly awaited.

LETTER TO THE EDITOR

London temperatures and the mercury-in-steel thermograph

In his interesting article on London temperatures in the March issue of the *Meteorological Magazine*, Mr. Marshall stated that the Bourdon tube of the mercury-in-steel distant-recording thermograph at the Meteorological Office is exposed in a Stevenson screen on the roof of Victory House. It is, of course, the bulb of the instrument which is exposed in the screen; the Bourdon tube forms part of the recorder which is installed inside the building.

Mercury-in-steel thermometers consist essentially of three parts, the bulb, the connecting tube and the Bourdon tube, all made of steel and welded together to form a closed system which is filled with mercury under pressure. The bulb, which is about 10-in. long and ⅝-in. diameter, is nickel-plated and then copper-plated for protection against corrosion. The Bourdon tube is flat in section and is coiled into a spiral, one end of which is attached to the spindle of the recorder pen arm. Expansion of the mercury due to increase in temperature of the bulb causes the spiral to uncurl and so moves the pen. No backlash occurs since the Bourdon tube itself acts as a spring. The capillary tubing connecting the bulb and the Bourdon tube may be as much as

150 ft. long but if lengths of more than 20 ft. are used, compensation for the effect of the capillary being at a different temperature from the bulb is provided by enclosing a certain volume of invar steel, which has a very low coefficient of expansion, into the capillary. The mercury-in-steel thermograph is one of the most reliable distant-recording thermometers available for meteorological purposes.

May 12, 1948 F. J. SCRASE

NOTES AND NEWS

Mr. John Dover

It was with great regret that we heard that Mr. John Dover, M.A., had decided, because of his advancing years, to give up his meteorological work at his home in Totland Bay, Isle of Wight. Mr. Dover began taking meteorological observations at Totland Bay in 1886. His rainfall observations were first sent to the British Rainfall Organization in 1888 and they have been published in *British Rainfall* since 1890. Full climatological returns were sent to the Meteorological Office in 1904 and summaries have been published in the *Monthly Weather Report* from 1904 onwards. In 1940, after Mr. Dover had supplied meteorological records for 52 years, the Director of the Meteorological Office presented him with an aneroid barometer in appreciation of his long voluntary service.

Mr. John Dover is a keen and experienced climatologist and has produced each year an exhaustive annual report, which contains not only a description, with a summary, of the observations of the year in question but also long-period averages of each of the elements and details of extremes of pressure, wind, temperature, rainfall and sunshine. In past years Mr. Dover paid occasional visits to the Meteorological Office and has always been pleased to co-operate in any way, such as supplying specific information for his station over a long period of years. Mr. Dover has therefore made a definite contribution to our knowledge of the climate of Totland Bay.

We wish Mr. Dover much future happiness and ask him to accept our sincere thanks for his long and accurate series of climatic observations.

HONOURS

The Birthday Honours List, June 1948, announced the appointment of Dr. C. E. P. Brooks, Assistant Director Climatology of the Meteorological Office, to be a Companion of the Imperial Service Order.

WEATHER OF MAY 1948

Depressions were centred over or near to the British Isles from the 1st to the 5th. An anticyclone then spread from the south-west, and pressure was generally high for four days. On the night of the 9th, the anticyclone having withdrawn to Scandinavia and northern Russia, a shallow depression began to move northwards from France, and lay over the North Sea until a new anticyclone advanced from the Atlantic on the 12th. Pressure was generally high over the British Isles from the 13th until the last few days of the month, except in the south during the passage of depressions on the 23rd and 26th, but became generally low on the 31st when a depression was centred over the Irish Sea. A striking feature of the maps for the last part of the month was the frontal system which extended across the subtropical Atlantic from Cuba to Spain. Depressions with central pressures as low as 996 mb. formed on this system over the Azores between the 20th and 22nd and south-west of Bermuda between the 24th and 26th.

For the month as a whole pressure exceeded 1020 mb. near the Azores. Over Europe and the western part of North America, and from Norway to Greenland, pressure was generally not more than 3 mb. above or below 1015 mb., and was for the most part within 3 mb. of the average.

The weather over the British Isles was distinguished by a notable excess of sunshine. Cool unsettled weather occurred at the beginning of the month and from the 22nd onwards but the intervening period was warm.

The first four days were cool and unsettled with rain at times and local thunderstorms on the 1st and 2nd. Subsequently a belt of high pressure extended from the south-west of Ireland across the British Isles to the White Sea and fair weather prevailed during the 6th–9th. Thereafter a spell of rather unsettled thundery weather ensued until the 13th. On the 14th a large anticyclone moved north-east over the British Isles to the North Sea and on the 19th and 20th a new anticyclone moved south-east from a position north-west of Iceland; warm fair weather, with abundant sunshine, prevailed until the 21st. By the 22nd pressure was highest over Greenland with a wedge extending south to the west of Ireland and cool polar air brought a considerable fall of temperature to northern districts of the British Isles on the 22nd and to southern districts on the 23rd. Subsequently cool unsettled weather was re-established and persisted until the end of the month. Local thunderstorms were reported daily from the 24th to the 31st.

The warm spell around the middle of the month was noteworthy; temperature reached or exceeded 80°F. at a number of stations in the period 17th–19th. On the other hand low screen minima were registered locally at times, particularly on the 1st, 2nd, 3rd, 24th and 25th.

The rainfall distribution was variable; in Scotland more than the average was confined to eastern districts from the Moray Firth to the Firth of Forth, while more than twice the average occurred locally in Angus and at Inverness. In England and Wales, broadly speaking, more than the average occurred south-east of a line from the Humber to Carmarthenshire. More than 200 per cent. occurred over much of an area extending from Norfolk across the Cotswolds to west Dorset.

The general and substantial excess of bright sunshine was a notable feature of the weather of the month. At numerous stations it was the sunniest May on record.

The general character of the weather is shown by the following table:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	82	22	+0·2	116	−3	129	50
Scotland	84	21	+0·2	77	−2	135	46
Northern Ireland ..	78	26	−0·2	80	−6	132	47

RAINFALL OF MAY 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	2·77	157	*Glam.*	Cardiff, Penylan ..	4·01	164
Kent	Folkestone, Cherry Gdns.	1·84	110	*Pemb.*	St. Ann's Head ..	1·81	90
"	Edenbridge, Falconhurst	2·75	148	*Card.*	Aberystwyth	1·04	50
Sussex	Compton, Compton Ho.	3·51	158	*Radnor*	Bir. W. W., Tyrmynydd	4·59	134
"	Worthing, Beach Ho. Pk.	1·70	103	*Mont.*	Lake Vyrnwy	3·39	100
Hants.	Ventnor, Roy. Nat. Hos.	2·74	161	*Mer.*	Blaenau Festiniog ..	3·27	58
"	Bournemouth	2·01	114	*Carn.*	Llandudno	·91	51
"	Sherborne St. John ..	2·93	151	*Angl.*	Llanerchymedd ..	2·01	86
Herts.	Royston, Therfield Rec.	2·96	153	*I. Man.*	Douglas, Boro' Cem. ..	2·60	104
Bucks.	Slough, Upton ..	2·95	176	*Wigtown*	Port William, Monreith	·92	39
Oxford	Oxford, Radcliffe ..	4·96	265	*Dumf.*	Dumfries, Crichton R.I.	2·33	85
N'hant.	Wellingboro', Swanspool	3·08	159	"	Eskdalemuir Obsy. ..	1·77	54
Essex	Shoeburyness	1·35	104	*Roxb.*	Kelso, Floors	1·33	69
Suffolk	Campsea Ashe, High Ho.	1·37	91	*Peebles.*	Stobo Castle	2·16	95
"	Lowestoft Sec. School ..	2·32	144	*Berwick*	Marchmont House ..	1·87	76
"	Bury St. Ed., Westley H.	3·44	189	*E. Loth.*	North Berwick Res. ..	1·34	67
Norfolk	Sandringham Ho. Gdns.	4·22	231	*Midl'n.*	Edinburgh, Blackf'd. H.	2·34	114
Wilts.	Bishops Cannings ..	3·92	201	*Lanark*	Hamilton W. W., T'nhill	·95	40
Dorset	Creech Grange.. ..	2·26	111	*Ayr*	Colmonell, Knockdolian	·95	37
"	Beaminster, East St. ..	4·57	222	"	Glen Afton, Ayr San. ..	1·57	52
Devon	Teignmouth, Den Gdns.	2·35	128	*Bute*	Rothesay, Ardencraig ..	1·70	56
"	Cullompton	4·01	186	*Argyll*	L. Sunart, Glenborrodale	1·79	50
"	Barnstaple, N. Dev. Ath.	2·15	104	"	Poltalloch	1·24	43
"	Okehampton, Uplands	2·64	98	"	Inveraray Castle ..	2·96	75
Cornwall	Bude School House ..	2·24	122	"	Islay, Eallabus ..	1·20	45
"	Penzance, Morrab Gdns.	3·00	136	"	Tiree	1·73	69
"	St. Austell, Trevarna ..	2·26	93	*Kinross*	Loch Leven Sluice ..	3·08	126
"	Scilly, Tresco Abbey ..	1·84	109	*Fife*	Leuchars Airfield ..	2·58	132
Glos.	Cirencester	4·70	228	*Perth*	Loch Dhu	2·76	61
Salop	Church Stretton ..	2·13	84	"	Crieff, Strathearn Hyd.	2·12	85
"	Cheswardine Hall ..	1·70	77	"	Blair Castle Gardens ..	..	..
Staffs.	Leek, Wall Grange P.S.	1·22	49	*Angus*	Montrose, Sunnyside ..	3·21	157
Worcs.	Malvern, Free Library	2·90	134	*Aberd.*	Balmoral Castle Gdns...	3·46	149
Warwick	Birmingham, Edgbaston	2·48	116	"	Dyce, Craibstone ..	3·44	135
Leics.	Thornton Reservoir ..	2·52	125	"	Fyvie Castle	2·92	113
Lincs.	Boston, Skirbeck ..	2·91	165	*Moray*	Gordon Castle	1·92	91
"	Skegness, Marine Gdns.	2·80	165	*Nairn*	Nairn, Achareidh ..	2·38	134
Notts.	Mansfield, Carr Bank	2·17	102	*Inv's*	Loch Ness, Foyers ..	3·78	55
Ches.	Bidston Observatory ..	1·14	60	"	Glenquoich	..	..
Lancs.	Manchester, Whit. Park	1·10	52	"	Fort William, Teviot ..	1·42	36
"	Stonyhurst College ..	1·51	53	"	Skye, Duntuilm ..	1·49	52
"	Blackpool	1·65	76	*R. & C.*	Ullapool	·99	40
Yorks.	Wakefield, Clarence Pk.	·99	50	"	Applecross Gardens ..	2·30	71
"	Hull, Pearson Park ..	1·95	101	"	Achnashellach	2·92	69
"	Felixkirk, Mt. St. John	1·01	54	"	Stornoway Airfield ..	1·22	50
"	York Museum	1·21	61	*Suth.*	Lairg	2·44	96
"	Scarborough	1·44	75	"	Loch More, Achfary ..	1·72	39
"	Middlesbrough.. ..	1·20	63	*Caith.*	Wick Airfield	1·69	82
"	Baldersdale, Hury Res.	1·46	57	*Shet.*	Lerwick Observatory ..	1·85	89
Norl'd	Newcastle, Leazes Pk.	1·76	89	*Ferm.*	Crom Castle	2·45	88
"	Bellingham, High Green	1·66	69	*Armagh*	Armagh Observatory ..	2·29	96
"	Lilburn, Tower Gdns...	1·24	54	*Down*	Seaforde	3·42	130
Cumb.	Geltsdale	1·39	54	*Antrim*	Aldergrove Airfield ..	1·72	76
"	Keswick, High Hill ..	1·22	38	"	Ballymena, Harryville..	1·28	45
"	Ravenglass, The Grove	1·38	49	*Lon.*	Garvagh, Moneydig ..	1·90	74
Mon.	Abergavenny, Larchfield	3·69	138	"	Londonderry, Creggan	2·03	77
Glam.	Ystalyfera, Wern House	4·16	119	*Tyrone*	Omagh, Edenfel ..	1·39	54

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, JANUARY 1948

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
	Mean of day M.S.L.	Diff. from normal	Absolute		Mean values							Total	Diff. from normal	Days	Daily Mean	Percentage of possible
			Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb							
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	998·8	−18·1	56	31	48·2	39·2	43·7	+3·2	41·3	88	7·9	3·57	+1·81	22	1·3	15
Gibraltar	1020·3	−1·2	72	42	62·9	51·9	57·4	+2·5	53·9	91	6·2	7·24	—	16	5·1	51
Malta	1015·7	−1·3	66	44	61·0	51·7	56·3	+1·0	53·9	74	5·0	1·19	—	10	6·6	66
St. Helena	1015·0	0·0	81	58	71·7	60·0	65·9	+2·2	60·3	96	9·2	2·66	+0·43	17	—	—
Freetown, Sierra Leone	1011·0	+1·7	88	69	84·1	73·1	78·6	−0·2	72·3	80	4·7	0·00	−0·41	0	8·2	70
Lagos, Nigeria ..	1010·7	+1·1	92	60	89·3	68·7	79·0	−1·9	74·1	83	6·0	0·00	—	0	6·0	51
Kaduna, Nigeria ..	1010·7	—	94	55	88·5	58·9	73·7	+0·1	53·8	18	1·9	0·00	0·00	0	8·6	75
Chileka, Nyasaland	1012·0	−0·1	91	62	83·2	66·9	75·1	0·0	69·5	75	6·4	5·20	−3·39	13	6·6	51
Lusaka, Rhodesia ..	1010·0	+0·2	87	59	78·7	62·9	70·8	+0·1	65·3	81	7·8	7·78	−2·57	20	4·9	—
Salisbury, Rhodesia ..	1011·0	+0·2	85	55	78·4	60·3	69·3	+0·3	62·5	73	6·2	7·18	−0·53	18	6·5	50
Cape Town ..	—	—	99	51	81·5	61·0	71·3	+1·4	62·1	70	3·1	0·14	−0·54	4	—	—
Germiston, South Africa	1011·0	—	89	51	78·4	57·7	68·1	—	58·2	67	3·8	3·61	—	12	8·7	64
Mauritius																
Calcutta, Alipore Obsy.	1015·7	−0·1	87	54	80·5	58·6	69·5	+2·9	59·5	87	2·4	0·81	+0·39	2	6·7	61
Bombay	1012·4	−1·2	90	61	83·2	68·3	75·7	+0·2	66·0	76	3·7	0·34	+0·24	5	7·6	68
Madras	1013·4	−0·7	85	65	83·5	69·7	76·6	+0·4	70·9	89	4·0	2·16	+1·02	7	8·8	77
Colombo, Ceylon ..	1010·8	0·0	91	70	87·6	72·6	80·1	+0·6	72·0	89	4·8	4·52	+1·27	12	8·3	70
Singapore	1010·8	+0·4	91	71	84·5	73·0	78·7	−1·0	74·8	86	8·1	19·81	+9·92	22	—	—
Hongkong	1021·4	+1·7	75	39	65·7	54·4	60·1	−0·1	54·6	72	—	1·24	−0·08	9	5·6	51
Sydney, N.S.W. ..	1015·2	+2·8	82	55	73·7	61·8	67·7	−3·9	62·6	69	6·1	9·02	+5·35	16	6·7	48
Melbourne	1016·5	+3·6	104	49	77·1	55·3	66·2	−1·2	57·5	58	6·1	1·23	−0·66	9	9·4	65
Adelaide	1017·4	+4·4	110	50	82·8	59·1	70·9	−2·8	59·0	39	3·2	0·14	−0·58	4	11·0	78
Perth, W. Australia	1014·6	+2·1	100	53	85·6	63·1	74·3	+0·5	64·5	48	2·7	0·06	−0·28	2	10·6	87
Coolgardie	1014·3	+2·9	107	53	94·7	64·7	79·7	+2·3	63·5	48	1·9	0·09	−0·37	2	—	—
Brisbane	1012·7	+1·4	88	62	81·8	65·7	73·7	−3·5	66·1	65	5·3	4·78	−1·67	11	8·9	65
Hobart, Tasmania ..	1016·6	+6·3	95	45	69·9	51·7	60·8	−1·2	53·9	58	6·1	1·10	−0·73	11	8·3	56
Wellington, N.Z. ..	1014·7	+1·4	82	50	71·0	57·2	64·1	+2·9	59·3	69	6·2	3·44	+0·11	9	8·1	55
Suva, Fiji	1006·9	−0·6	91	71	86·1	75·1	80·6	+0·7	76·5	85	8·1	7·09	−4·34	24	5·0	38
Apia, Samoa ..	1008·2	+0·3	93	71	86·5	74·6	80·5	+0·4	77·7	81	7·5	17·02	−0·74	25	5·5	43
Kingston, Jamaica ..																
Grenada, W. Indies	1012·6	−0·2	85	63	84·2	73·5	78·9	+1·8	73·5	79	5·7	4·96	+0·58	23	—	—
Toronto	1020·4	+2·5	39	−12	25·5	10·9	18·2	−4·0	15·4	—	7·6	1·57	−1·22	13	3·7	40
Winnipeg	1019·6	−1·3	29	−36	8·4	−9·9	−0·7	+3·2	−3·8	—	5·5	0·59	−0·32	10	3·8	44
St. John, N.B. ..	1014·5	−1·0	39	−9	24·9	9·9	17·4	−1·8	13·9	—	6·5	5·11	+0·31	16	3·0	33
Victoria, B.C. ..	1022·5	+6·5	49	22	43·5	32·9	38·2	−0·8	35·1	90	7·0	4·25	−0·29	14	3·0	34

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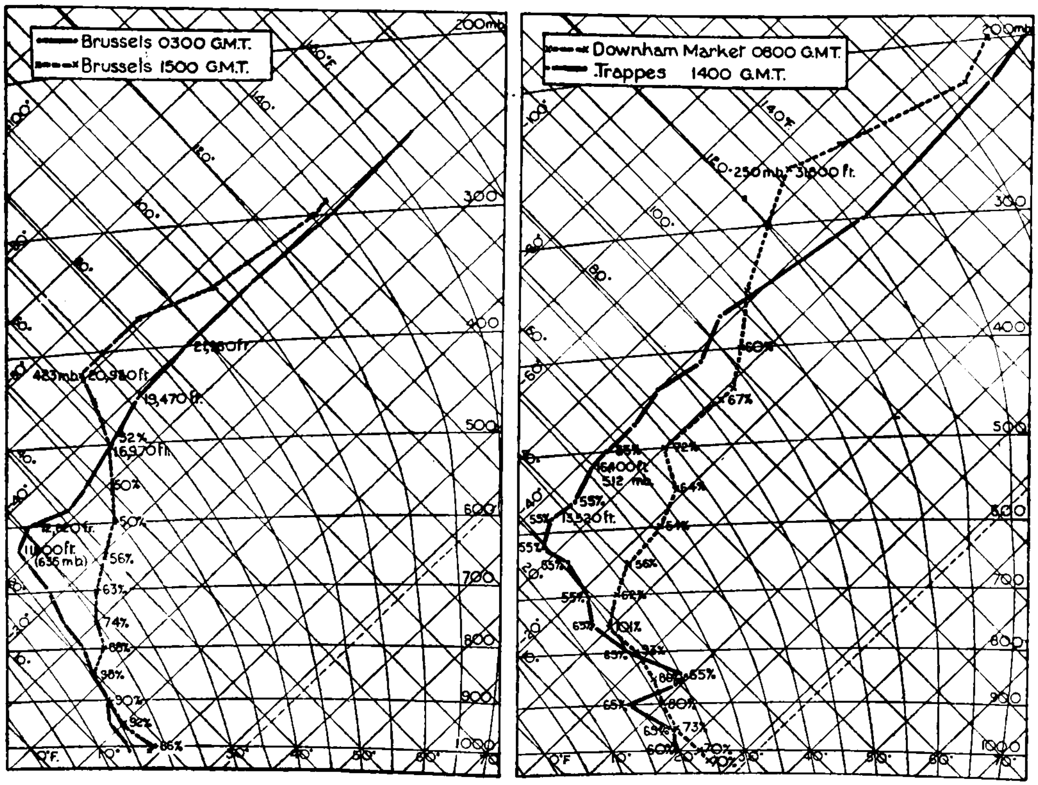
AN UNUSUAL VERTICAL TEMPERATURE DISTRIBUTION OVER BRUSSELS AND PARIS

BY C. K. M. DOUGLAS, B.A.

The radio-sonde ascents at Brussels at 0300 G.M.T. on February 20, 1948, and at Paris (Trappes) at 1400 on the same day (Fig. 1) revealed an atmospheric structure which is probably almost unique in western Europe. At Brussels the temperature at 650 mb., slightly below the inversion, was 39°F. below the February normal, but at 450 mb. it was only 16°F. below normal. (These figures are based on the 23-yr. average for February in East Anglia. The mean isotherms in winter are orientated roughly north-west to south-east, so that the Brussels normals cannot be appreciably different.) At Paris the lower layers were only slightly less cold, though there was a peculiar inversion at 900 mb. The Paris tropopause was at the astonishing level of 580 mb. (13,520 ft.). At Brussels the tropopause was at 450 mb. (19,500 ft.) but the lapse rate from 550 to 450 mb. was only 2·8°C./Km., not much above the lapse rate which is the accepted convention for determining the tropopause height. This is based on a fall of 2°C. in a complete kilometre, which was not observed on the Paris sounding above 13,520 ft. Since there must be a convention of this type in order to fix the height of the tropopause, it is obvious that the tropopause is not on all occasions a well defined physical entity.

The relative humidities reported from Brussels are not included as they appear to be too high, being over 100 per cent. up to the inversion and over 80 per cent. up to the tropopause. The Paris ascent was considerably drier and the morning ascent at Utrecht (de Bilt) showed similar humidities to those at Paris. Its temperature distribution was rather like that at Brussels, but there was a lapse of 9°F. from 560 mb. to the tropopause at 500 mb. The weather was mainly fine on the Continent, but there was local snow in which saturation was probable from the cloud base to the top of the very cold air.

The second curve in Fig. 1(*a*) illustrates the rapid change of structure over Brussels in 12 hours. The other curve in Fig. 1(*b*) shows the temperature and humidity at 0800 over Downham Market, when temperature was at its lowest. The temperature of −14°F. at 700 mb. was 29°F. below normal and one of the



(a) (b)

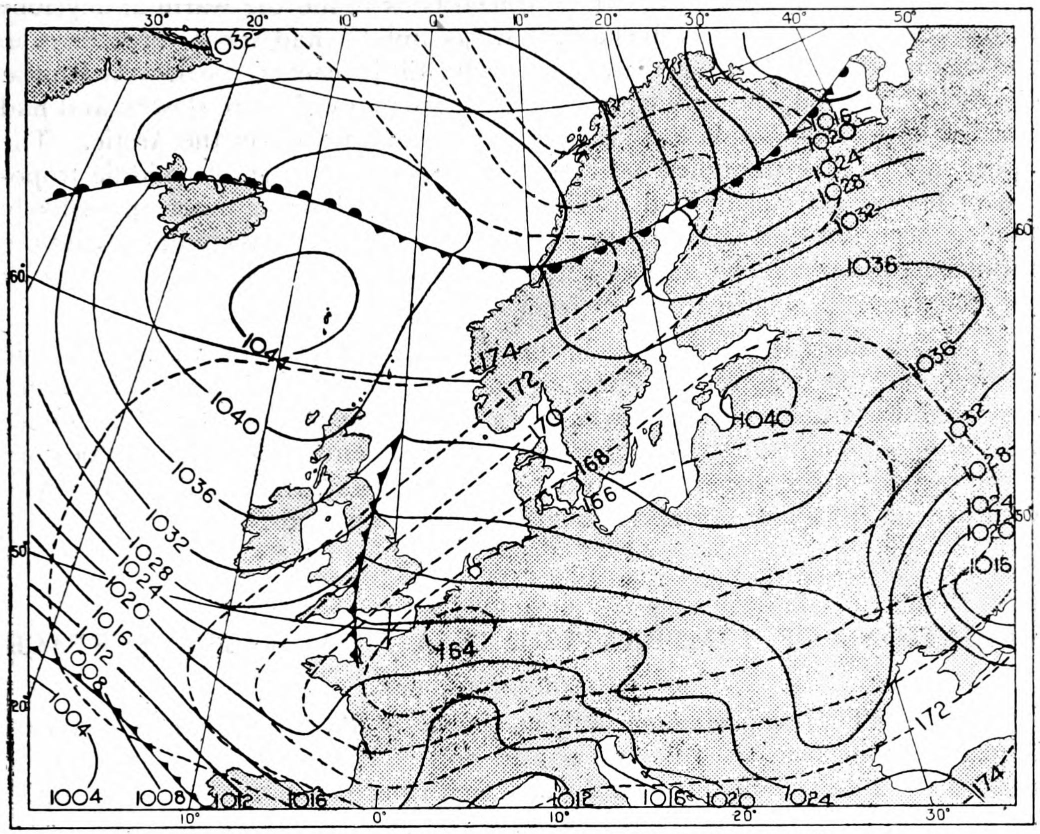
FIG. 1—TEPHIGRAMS OF RADIO-SONDE ASCENTS ON FEBRUARY 20, 1948
Relative humidities are written at the side of each ascent.

lowest ever recorded at that pressure in the British Isles, though it was 8°F. higher than at Brussels at 0300. The tropopause was as high as 31,800 ft.

It is impossible to give any adequate explanation of the abnormal atmospheric structure. On the previous day the tropopause over and to eastward of the area was at about 300 mb., and the associated potential temperature was about 30°F. above that at 500 mb. on February 20 in the continental region we are considering. This shows that the whole thick stable layer, including what was technically the upper troposphere and lower stratosphere, was developed between the 19th and 20th, by a combination of factors, out of the rather stable middle and upper tropospheric air of the 19th. Much more detailed information as to wind, temperature, and humidity over the area would be required in order to elucidate the problem.

Fig. 2 shows the distribution of sea-level pressure at 0600, and also the thickness contours of the height of the 500-mb. surface above the 1000-mb. surface at 0300, which is proportional to the mean temperature of the layer between those surfaces. These indicate a cold pool centred very near Brussels, with an extension to central Europe. The cold pool was formed out of a cold tongue which had previously extended south-south-west across Russia from the White Sea and then west-south-west round the boundary of the anticyclone to northward. The cold pool became detached from its parent cold tongue and moved west-south-west, finally reaching the Bay of Biscay in a weakened condition on the 22nd.

This period was remarkable for the amount of dry snow which fell in south-east England, including the London area. In about 48 hours, beginning on the


30°
20°
10°
0°
10°
20°
30°
40°
50°
60
50
20
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1016
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1024
1028
1032
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1020
1016
1012
1008
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174
172
170
168
166
164
1040
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1024
1020
1016
172
174
1004
1008
1012
1016
1012
1016
1020
1024
10°
0°
10°
20°
30°

FIG. 2—SYNOPTIC CHART, FEBRUARY 20, 1948
Sea-level isobars (full lines) and fronts are at 0600 G.M.T.; 1000 to 500-mb. thickness lines (pecked lines) are at 0300 G.M.T.

morning of February 20, 10 in. fell over much of Kent, Sussex, and Surrey, and Biggin Hill had 14 in. Appreciable falls also occurred in south-west England, including the Scilly Isles. The snowfalls developed within a continental air mass with a comparatively short sea track, and were much the heaviest falls of this character within recent decades. The snow was of instability type but it sometimes lasted for hours, associated with minor troughs of low pressure moving westward, and a general slow fall of pressure. It is well known that moving cold pools are liable to produce these effects, but the process is not fully understood. On February 20 there were large cumulus clouds over land with a surface temperature of about 24°F.

The upper wind structure over England on that day was of considerable interest. Since the cold air came from the north-east it might be thought at first sight that in the layer where the lapse rate decreased the NE. wind would also decrease with height. Actually the presence of a warm anticyclone to northward indicated that the opposite structure was more likely, and this was in fact observed. The 0900 observations at Downham Market, corresponding to the temperatures shown in Fig. 2, were as follows:—

Pressure	Wind		Pressure	Wind	
mb.	°true	kt.	mb.	°true	kt.
900	070	36	500	060	91
800	050	48	400	060	135
700	050	45	300	060	144
600	060	65			

The air at 500 and 300 mb. can be traced back round the warm anticyclone to the region south-west of Iceland. At 500 mb. it had spent three days in the area north of 65°N., but it was over water till it reached north-west Russia. On the other hand, the very cold air lower down moved more slowly, and had reached north-west Russia from the permanent cold pool over the Arctic. The rather low relative humidity indicates that the air in the stable middle troposphere had probably subsided to some extent, but this was much more likely to have occurred during February 16 to 19, when the air was coming round the anticyclone, than on the 20th, when there was a slight cyclonic curvature of the isobars at all heights from sea level to 500 mb.

It is often found that when an air current increases upwards, without change of direction, the trajectories of the air at different levels diverge widely after they have been followed backwards or forwards for a day or two. The upper instability often noted in strong SE.–SW. upper currents on a cyclonic trajectory is the reverse of the upper stability in a case like this, which is liable to occur with a wind from any northerly point increasing upwards.

VARIATIONS OF TEMPERATURE IN A FREE WATER SURFACE

BY K. STORMONTH, B.SC.

Introduction.—The evaporimeter tank in service at Rye is of $\frac{1}{8}$-in. galvanised iron, measuring 6 ft. by 6 ft. and is 2 ft. deep. It is sunk in the ground for 1 ft. 10 in., a 2-in. flange, 0·4 in. thick, which runs outside the top of the tank, being exposed above the ground surface. The actual depth of the water varies of course, but to maintain a fair consistency of exposure this depth is kept as far as possible between 1 ft. $7\frac{1}{2}$ in. and 1 ft. 9 in. Still-water chambers, approximately 1 ft. square, are attached to two top corners of the tank for float and hook gauges respectively. The tops of these are level with the top edges of the tank proper.

Two sets of observations have been made, one in December 1946 and January 1947, the other in August 1947. The following aspects of variation were investigated:—

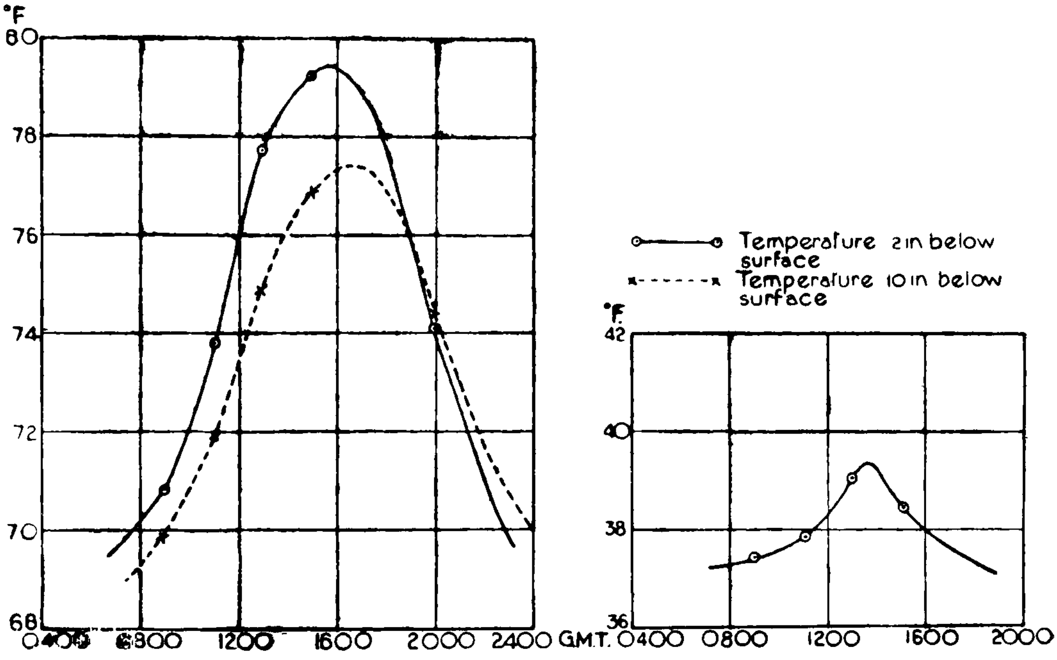
(1) Diurnal variation of temperature at a fixed point in the surface.
(2) Variation of temperature with depth below the surface.
(3) Horizontal variation of temperature in the surface.

Days of considerable solar radiation were selected as the variations were expected to be more considerable on such occasions. In the attached tables will be seen any available corresponding air and earth temperatures, sunshine durations, wind speeds at 4 ft. above ground and amounts of evaporation.

Method of observation.—Thermometers of the type used in Assmann psychrometers were used, the upper part of the stem being held in the hand and a reading being taken after very careful immersion so as not to disturb the temperature profile of the surface water. The possibility of radiation effects upon the thermometers was not overlooked, and whenever readings were being made care was taken to shield the thermometer bulb with the observer's body. The thermometer stems were calibrated for length, and measurements were taken from the mid points of the bulbs, which are themselves 0·65 in. long. It should be pointed out that the temperature gradients reported between depths of 1 in. and 2 in. should be accepted with reserve as it was most difficult to hold the thermometers in position long enough for an accurate reading at the same time maintaining a fixed depth to within a fraction of an inch.

Not on all occasions but whenever possible two observers took independent sets of readings.

Diurnal variations.—Readings were taken at a depth of 2 in. below the surface at a point 2–2½ ft. from the south-south-west wall of the tank. It is seen that the daily temperature range between sunrise and sunset in summer is approximately 4–5 times that experienced in winter. In summer, observations were taken on seven August days with considerable sunshine, and the mean hourly values have been plotted in Fig. 1(*a*). For winter, five sunny days in December and January have been similarly treated. Mean values at a depth of 10 in. have also been drawn for August, but there was insufficient vertical gradient in winter to permit of similar action. In summer, the maximum temperature at 2 in. deep would appear to be attained between 1500 and 1600 G.M.T., whilst the maximum at 10 in. is not reached until about an hour later, these approximate times being confirmed by separate and intermediate readings. In winter, the 2-in. maximum temperature is attained earlier at about 1300–1400, this also being confirmed by individual tests. Winter values are shown in Fig. 1(*b*).



(*a*) (*b*)

FIG. 1—DIURNAL VARIATION OF WATER TEMPERATURE TEMPERATURE AT A POINT 2–2½ FT. FROM NEAREST WALL OF TANK

(*a*) 7 sunny days, August 1947, (*b*) 5 sunny days, December 1946–January 1947.

Variation of temperature with depth below surface.—Readings were taken at a point 2–2½ ft. from the side of the tank at depths of 1, 2, 3 and 10 in. below the surface. Fig. 2 illustrates the summer results. Studying this figure and Fig. 1(*a*) the greatest overall decrease of temperature with depth is seen to occur some time between 1300 and 1400 G.M.T., whilst by 2000, a reverse

TABLE I—MEANS FOR DAYS OF CONSIDERABLE SUNSHINE

TIME	WATER TEMPERATURE							AIR TEMPERATURE				EARTH TEMPERATURE						SUNSHINE	WIND 4 FT.	EVAPORATION
G.M.T.	1 in. deep at distances from south-south-west side			2–2½ ft. from side at depths of																
	1 in.	1 ft.	2½ ft.	1 in.	2 in.	3 in.	10 in.	Dry	Wet	Max.	Min.	1 in.	2 in.	4 in.	8 in.	1 ft.	4 ft.			
								degrees Fahrenheit										hr.	m.p.h.	in.
AUGUST 1947, 7 days																				
0900	72·0	71·8	71·1	71·0	70·8	70·2	69·8	74·5	67·8	82·6	57·3	71·7	68·7	65·8	65·9	66·4	60·1	12·2	5·4	(*a*) 0·123
1100	75·1	74·9	74·4	74·5	73·8	73·4	71·9	79·3	69·8	—	—	78·8	73·8	68·4	66·7	—	—	—	5·4	
1300	79·0	78·7	78·4	78·3	77·7	76·9	74·9	81·7	69·3	—	—	83·5	78·7	71·2	67·8	67·2	—	—	6·2	(*b*) 0·026
1500	79·4	79·2	79·0	79·1	79·2	78·7	76·9	81·2	68·4	—	—	82·9	80·3	73·2	68·7	67·8	—	—	5·6	
2000	73·9	74·1	74·0	73·9	74·1	74·3	74·4	62·8	60·5	—	—	68·8	70·1	71·1	69·6	68·0	—	—	1·3	
DECEMBER 1946 to JANUARY 1947, 5 days																				
0900	—	—	—	—	37·4	—	—	32·8	32·1	40·8	29·2	—	—	—	39·8	42·4	48·4	5·2	5·6	(*a*) 0·012
1100	37·9	37·8	37·8	37·8	37·8	37·9	38·2	36·6	—	—	—	—	—	—	40·0	—	—	—	6·0	
1300	—	—	—	—	39·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(*b*) —
1500	—	—	—	—	38·4	—	—	36·9	35·4	—	—	—	—	—	39·8	—	—	—	5·2	

gradient, i.e. increase of temperature with depth is established to a distance of at least 4–5 in. It will be noticed that the marked decrease of temperature with depth between 1 and 3 in. seen at 1300 has decreased markedly or even vanished by 1500. Even allowing for the difficulties of measuring in the surface mentioned above, this phenomenon can be asserted for August, a special study having been made on this point. In winter, little variation with depth occurs, the average 10-in. reading at 1100 being 0·4°F. higher than that for 1–2 in.

Variation of temperature horizontally.—The south-south-west wall of the tank is subject to solar radiation upon the top two to three inches, and this has an effect upon the temperature of the adjacent water. Holding the bulb at a depth of 1 in. in each case, readings were taken at distances of 1 in., 1 ft. and 2½ ft. from the wall in question. As expected, the effect was more marked in summer. By day water near the wall was warmed, a reverse cooling effect being noticed later in the evening. The effect did not extend beyond a distance of 2½ ft. from the south-south-west wall.

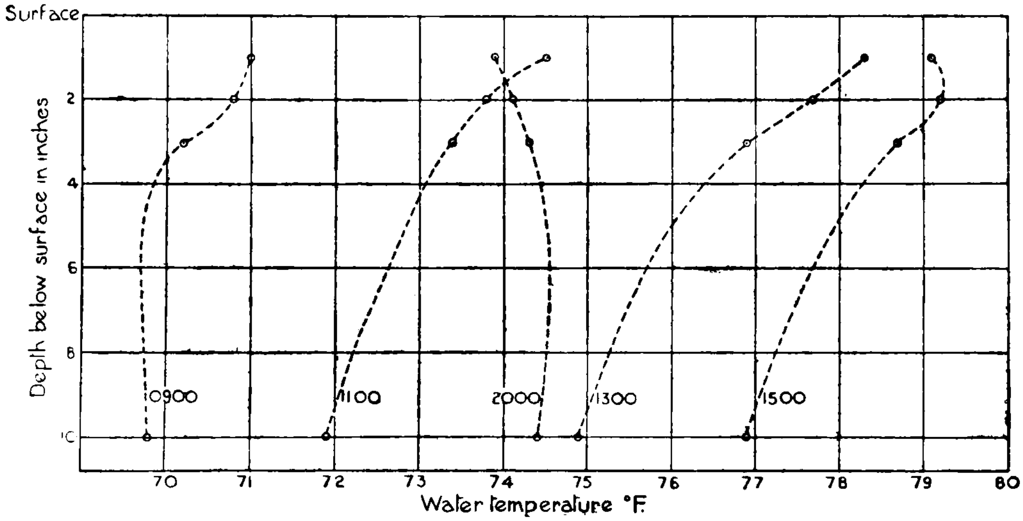


FIG. 2—VARIATION OF WATER TEMPERATURE WITH DEPTH AT A POINT 2–2½ FT. FROM THE NEAREST WALL OF TANK FOR 7 AUGUST DAYS WITH CONSIDERABLE SUNSHINE

Additional notes regarding data.—Wind readings were taken by means of recording electric cup anemometers, and hourly values noted were mean speeds for periods of 30 minutes centred around the particular times of observation.

Evaporation readings quoted are (*a*) means for periods of 24 hr. commencing at 0900 G.M.T. and (*b*) means for periods of 6 hr. also commencing at 0900, on the days of observation.

Readings in column 4 of the tables (i.e. 1 in. deep, 2½ ft. from south-south-west wall) do not agree with corresponding values in column 5 (i.e. distant 2–2½ ft. from side at depth of 1 in.), as they do not necessarily refer to identical readings.

BOOKS RECEIVED

Observations made at the Royal Magnetic and Meteorological Observatory at Batavia, by H. P. Berlage, jr. Vol. LXVI A 1943 Meteorological observations. 4to, 15 in. × 10½ in. pp. vii + 63. Batavia [1948].

THE USE OF BAROGRAPHS IN SHIPS

BY J. R. BIBBY, B.A.

Autographic records from ships' barographs are often unsatisfactory because the pen draws not a line but a " ribbon " several millibars wide. For this reason open-scale barographs are rarely carried on ships, small barographs being normally used. Consequently ships are unable to report barometric tendencies with the high accuracy required for synoptic observations, and which is normally achieved at land stations.

There are four factors which may contribute to the broadening of the trace:—

(*a*) Vibration due to the ship's engines, etc.

(*b*) Movement of the pen-arm caused by angular accelerations of the ship (rolling and pitching).

(*c*) Transient pressure changes caused by gusts of wind.

(*d*) Oscillations of pressure due to the rise and fall of the ship.

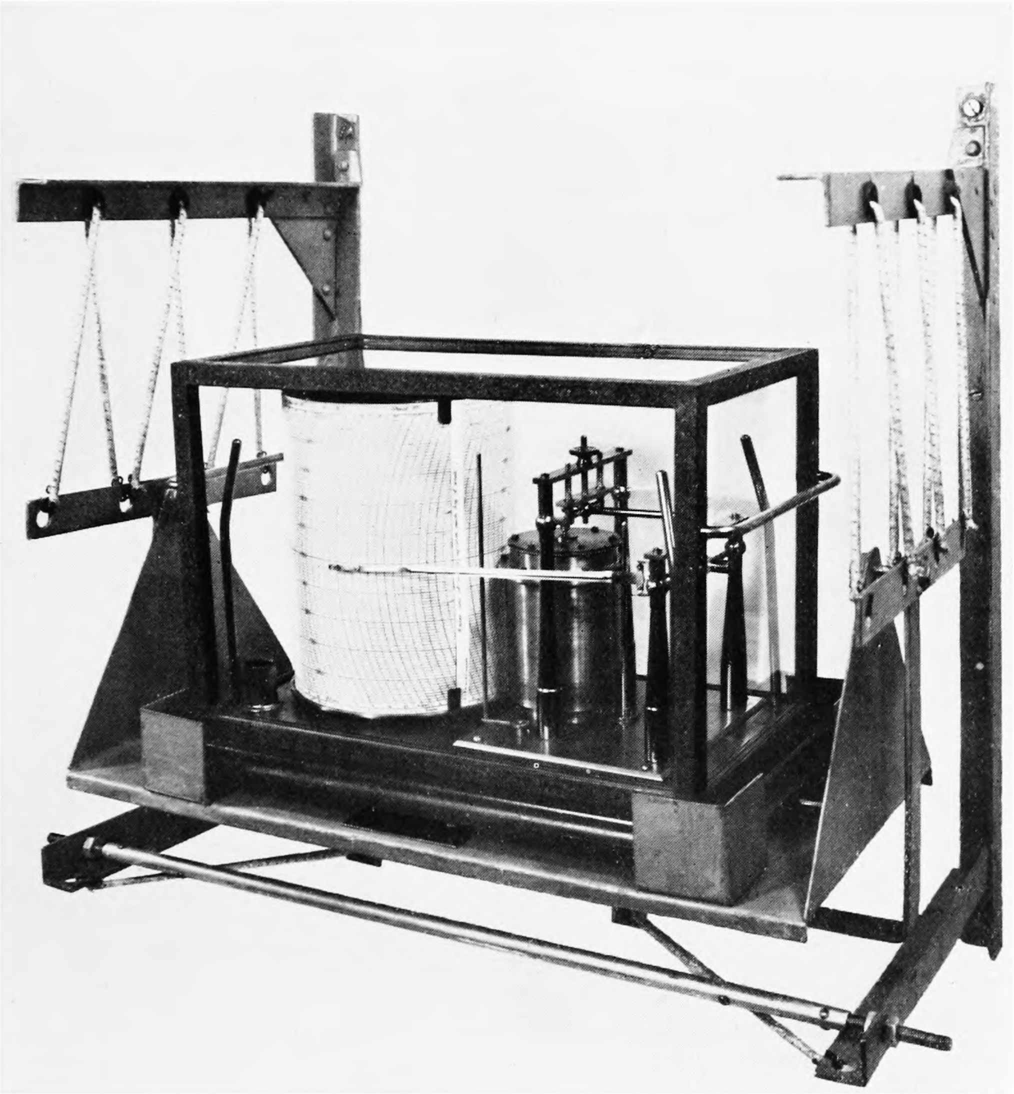
It is difficult to decide the relative magnitudes of these causes as all four usually act simultaneously, but two facts throw light on the question. First, barograms from the largest passenger liners are as a general rule no better than those from smaller craft. This indicates that gusts of wind play a large part in broadening the trace, as the other three factors would probably be much less in the case of a large ship. Secondly, trawlers' barograms often show sudden increases in the width of the trace when the steam winch is started up, showing that, here at least, vibration plays a large part.

It can therefore be concluded that, though different factors are likely to predominate in different types of ship, the chief causes of poor barograph traces are variations of pressure due to gusts of wind, and mechanical vibration. Experiments have recently been completed in the Instruments Branch of the Meteorological Office with the object of obtaining better records from ships' barographs, so enabling open-scale barographs to be used in ships. The experiments fell into two parts, one to reduce the effects of vibration and the other to reduce the effect of transient pressure fluctuations. The results of the experiments are described below.

Meteorological Office anti-vibration mounting for open-scale barographs.—This is illustrated in the photograph opposite, and consists of a metal tray to hold the barograph, suspended from fixed brackets by a number of elastic cords. The tray can swivel about an axis parallel to its longer edge, so as to prevent the ship's motion from throwing the pen off the chart.

Maximum freedom from vibration would be obtained by making the supporting elastics very weak, but a fairly stiff support is necessary to prevent excessive movement of the barograph in a rough sea. The present arrangement is thought to be about the best compromise in this respect, the supports being such that the period of oscillation of the shelf (with barograph in position) is about 0·5 sec. Favourable reports have been received from the ocean weather ships, and the only modification contemplated for the future is some elimination of the projecting edges and corners to reduce the risk of accidents.

Oil-damped barographs.—To prevent the barograph recording transient pressure changes it is necessary to introduce a delaying or " damping " factor in its response, as in the case of the marine barometer. The optimum degree



OIL-DAMPED BAROGRAPH ON ANTI-VIBRATION MOUNTING

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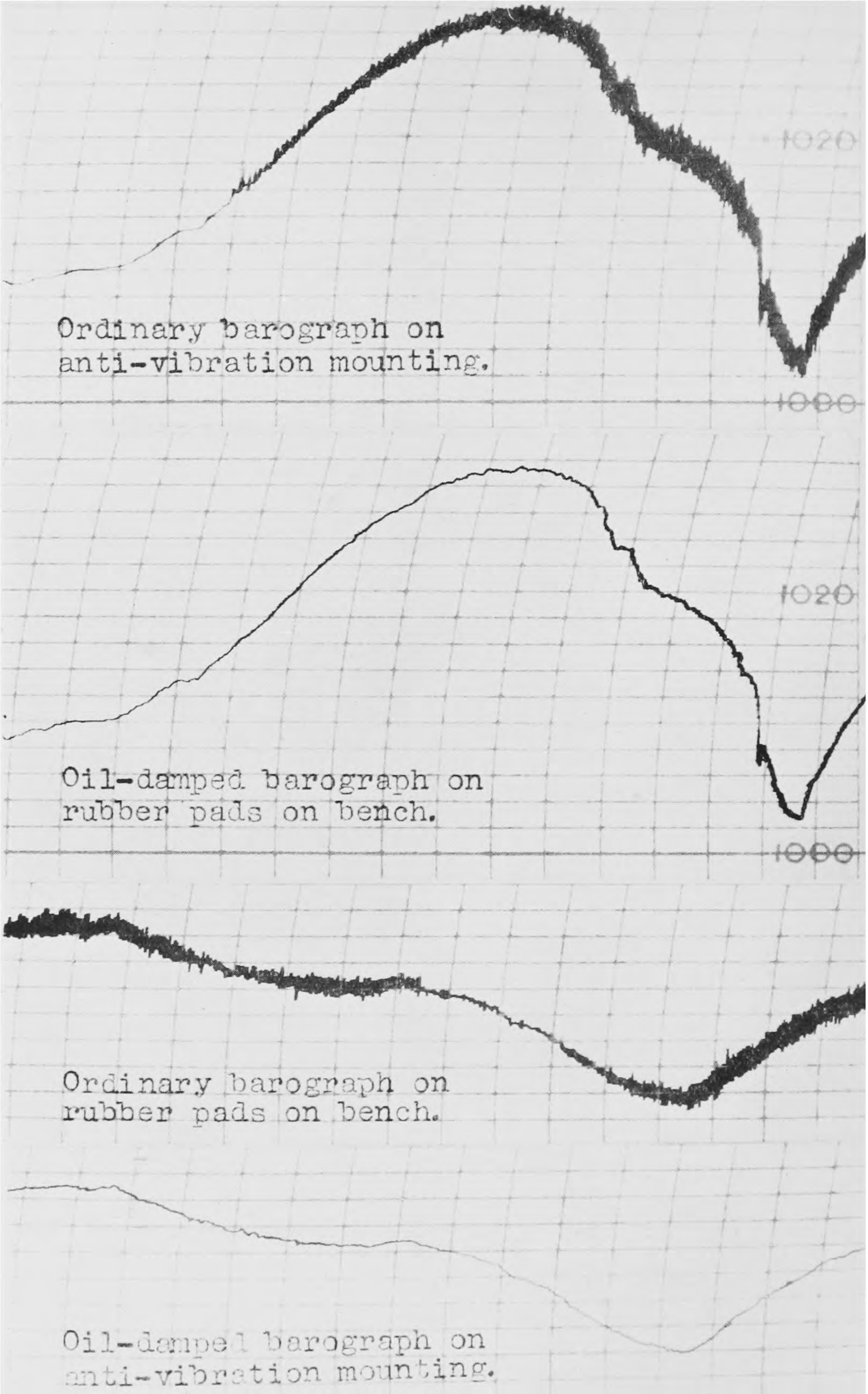


SPECIMEN BAROGRAMS TRACED ON BOARD THE *Weather Observer*
Upper two barograms from 1600 G.M.T., September 20, to 1600, September 22, 1947; lower two barograms from 1900 G.M.T., October 3 to 1900, October 5, 1947. Position of *Weather Observer:* Station I, 60°N. 20°W.

of damping requires a compromise between recording accurately large genuine barometric tendencies, but not recording spurious changes of pressure. Three extreme cases were considered, as follows:—

(*a*) Gusts of wind raise the pressure by 5 mb. for periods of five seconds at a time.

(*b*) The ship rises and falls over a total amplitude of 25 ft. with a period of 20 sec. The range of pressure variation corresponding to this range of height would normally be about 1 mb., but Sir Geoffrey Taylor has pointed out that this is only true if the velocity of the wind is the same as that of the waves. The pressure variation is doubled if there is no wind, and may be even greater if the wind has a component in the direction opposite to that in which the waves are travelling. Because of this the total amplitude of the pressure oscillation was assumed to be 3 mb.

(*c*) After falling at the rate of 6 mb./hr. the barometer starts rising at the same rate.

It was assumed in each case that the tendency (change of pressure in three hours) is required with an accuracy of 0·2 mb., and in (*a*) and (*b*) this was interpreted as restricting the total width of the trace to 0·4 mb. The required exponential lag coefficients can be calculated from these assumptions, and the minimum values were found to be 60 sec. in case (*a*) and 23 sec. in case (*b*). In case (*c*), if the tendency is required to an accuracy of 0·2 mb. the barograph must clearly not lag behind the actual pressure by more than 0·1 mb., which implies a maximum lag coefficient of 60 sec. (This assumes that the time scale is sufficiently open to allow such a rapid change to be read accurately.)

These figures imply that the lag coefficient should be exactly 60 sec. with no variation allowable. As this was not expected to be practicable the calculations were repeated, allowing errors of 0·4 mb. in the tendency in extreme cases. The permissible lag coefficients were then found to be (*a*) 29 sec. (minimum), (*b*) 11 sec. (minimum), (*c*) 120 sec. (maximum), so allowing a four to one ratio of lag coefficients.

The damping of the barograph movement was effected by the use of a viscous oil. This idea is not new, as a barograph widely used in the United States has vanes attached to the pen-arm spindle moving in oil-filled cylinders. In the present case, however, a different arrangement was used which eliminates any strain on the levers, and also prevents movement of the pen being allowed by looseness in the pivots. As shown in Fig. 1, the barograph bellows is inside a brass cylinder filled with oil, and can only expand or contract by forcing oil to flow through the narrow annular gap where the rod passes through the hole, A, in the top plate. (An enlarged view of the hole, with dimensions, is shown in Fig. 2.) For example, in the case of the Short and Mason open-scale barograph used for these experiments, a change of 1 mb. in the reading causes the passage of about 50 cu. mm. of oil through the annular gap. A brass plug, B, threaded both internally and externally, can be screwed down into the lid of the cylinder, so sealing it and allowing the barograph to be transported already filled.

One difficulty in the use of oil for this purpose is the large variation of viscosity with temperature. Experiment showed that with a fixed size of gap the lag cofficient was roughly proportional to the viscosity of the oil used, so

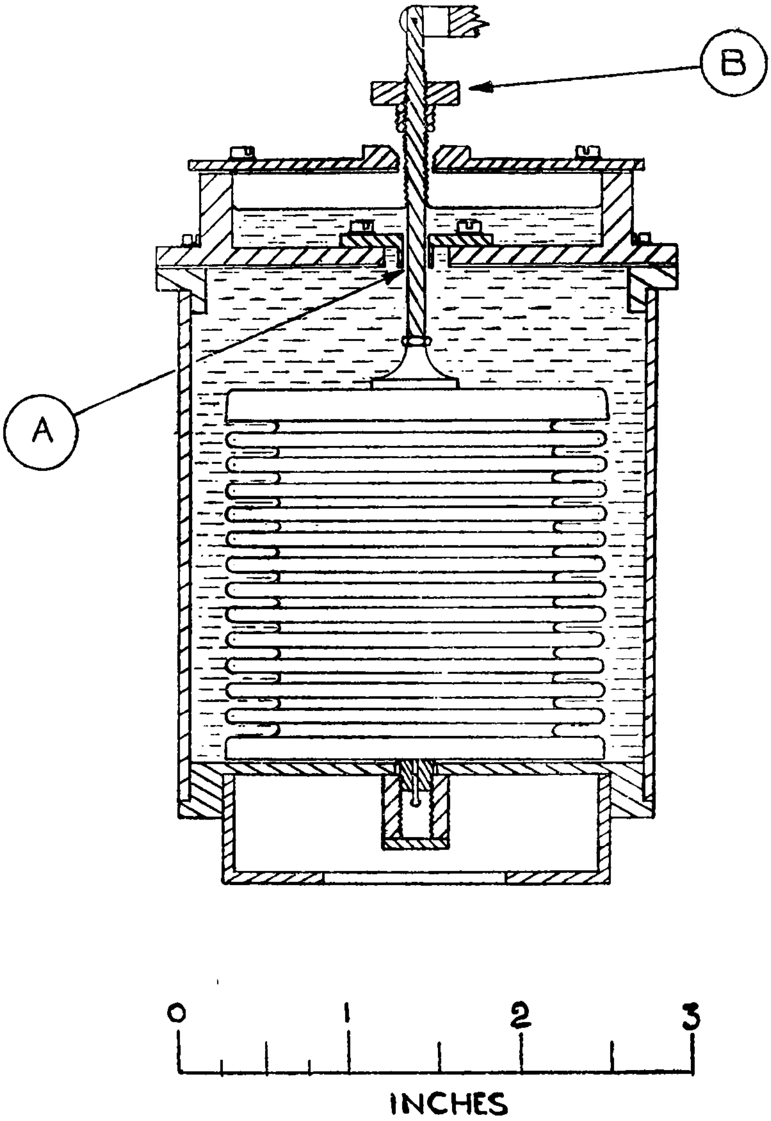


FIG. 1—CROSS-SECTION OF BELLOWS AND OIL CONTAINER

it was necessary to use an oil whose viscosity varied by not more than 4 : 1 over the range of temperatures likely to be experienced by a barograph in a ship. This was assumed to be 30°F. to 110°F.

The Government Chemist's Department was consulted, and they ascertained that the most favourable hydrocarbon oil had a viscosity variation of 12 : 1 over the required temperature range. They recommended the use of silicone fluids, which have a much lower temperature coefficient of viscosity. Several samples of different silicone fluids were tested and found to have viscosities varying by a factor of only 2·5 : 1 over the temperature range 30–110°F. The barograph, as finally made up for trials at sea, had the following lag coefficients:—

100 sec. at 30°F. 70 sec. at 70°F. 40 sec. at 110°F.

(The corresponding viscosities of the silicone fluid were approximately 100, 70, and 40 gm./cm./sec. respectively.)

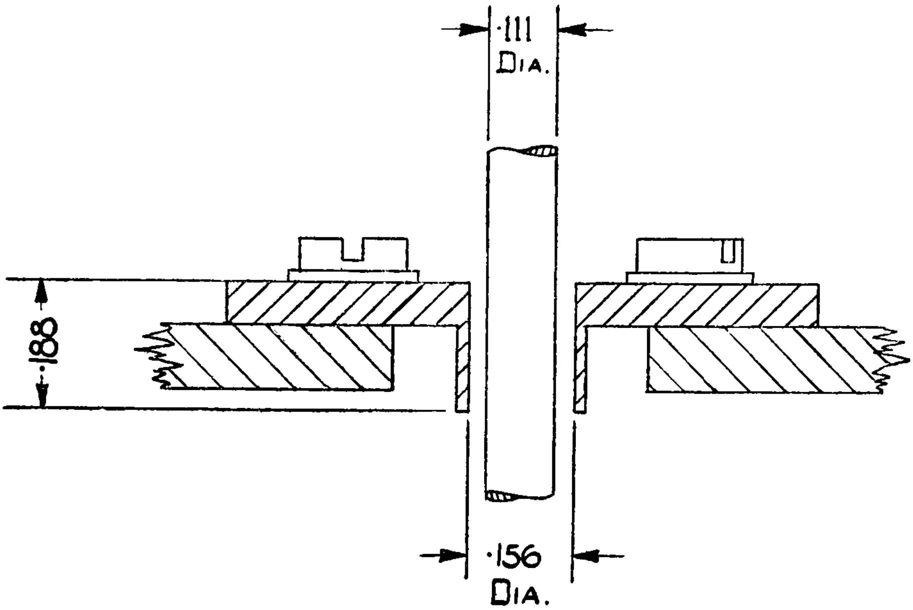


FIG. 2—ENLARGED VIEW OF ANNULAR GAP
(Dimensions are in inches)

Results of trials at sea.—The oil-damped barograph and an ordinary open-scale barograph have been carried in O.W.S. *Weather Observer* since September 1947, during which time much rough weather has been encountered. One barograph stands on the anti-vibration mounting and the other on sponge rubber pads on a bench, the two being interchanged periodically. The chief conclusions to be drawn from the barograms obtained (typical sections of which are shown in the photograph facing p. 177) are as follows:—

(*a*) The ordinary barograph often gives a trace 2–3 mb. wide, there being no visible improvement when on the anti-vibration mounting.

(*b*) The oil-damped barograph standing on the bench gives a trace hardly ever wider than 0·5 mb., and never wider than 1 mb.

(*c*) When the oil-damped barograph is on the anti-vibration mounting it is almost impossible to detect any broadening of the trace, which never exceeds 0·3 mb. This can be regarded as equivalent to a barogram at a sheltered land station.

It is therefore concluded that oil-damped barographs should be adopted for use at sea, and preferably also at land stations, or at least the more exposed ones. The relatively expensive silicone fluids (which cost nearly £1 per barograph) need only be used where wide variations of temperature are encountered, i.e. on voyages covering a big range of latitude. A much cheaper hydrocarbon oil could be used at land stations, and probably also on ships confined to temperate latitudes, including ocean weather ships.

It appears that the anti-vibration mounting should be used at sea when the very best results are required, or in ships especially subject to vibration. But if in any case the use of this mounting would be inconvenient, e.g. for lack of space, an oil-damped barograph standing on sponge rubber pads would give reasonable records.

METEOROLOGICAL RESEARCH COMMITTEE

The second meeting of the Instruments Sub-Committee was held on June 10, 1948. Three papers dealing with upper air observations were considered. One of these (*M.R.P.* No. 406 by Mr. J. K. Bannon) deals with the errors in computed upper winds based upon measurements made with GL Mk. III radar equipment. Another paper (*M.R.P.* No. 405 by Dr. R. Frith and Mr. H. C. Shellard) discusses the speed correction coefficient of the Meteorological Office electrical-resistance thermometer. There is some evidence that this coefficient varies with air density though this is not yet certain. The third paper (*M.R.P.* No. 398 by Mr. O. M. Ashford and Mr. H. J. Ferrer) reviews the development of the Meteorological Office radar reflector Mk. IIB.

The Sub-Committee also discussed the need for producing a relatively cheap radar method of measuring upper winds with, if necessary to secure cheapness, a smaller accuracy than is obtainable by the best of the present methods. Such equipment would be useful in parts of the world where financial or man-power reasons prohibit the use of current Meteorological Office equipment. It was decided to investigate the possibility of designing equipment to meet this need.

Other matters considered by the Sub-Committee included a proposed method of measuring the mean atmospheric transmission between ground level and a specified height, and the need for a special radio-sonde for measuring potential gradient.

The second meeting of the Synoptic and Dynamical Sub-Committee was held at Dunstable on June 24, 1948.

Reports on the methods which are being emphasised in the Forecasting Research Division in the study of medium and short-range changes in synoptic conditions and circulation patterns were considered and the possible use of electronic computing machinery in this connexion was also discussed.

It was decided that a number of tephigrams should be printed showing the saturated adiabats and the humidity mixing-ratio isopleths for condensation to water as well as for sublimation to ice, at subfreezing temperatures. In the former case, the lines will be printed in a distinctive colour. One or more copies of this diagram will be sent to each station; they will not be for general use, but merely to illustrate the differences between thermodynamical processes with respect to supercooled water and ice respectively.

The work on the seasonal variation of upper winds over the world has now been completed (*S.D.T.M.* No. 118, Parts I–VI), and the Sub-Committee heard how the task had been accomplished in the Climatological and Investigations Divisions; the charts and tables will be amended as necessary, as further data become available.

A paper (*M.R.P.* No. 392) on the angular deviation of the wind from the isobars by Mr. J. K. Bannon, was also discussed.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Royal Meteorological Society held on June 16, 1948, Dr. G. M. B. Dobson, President, in the Chair, Capt. C. E. N. Frankcom (Superintendent, Marine Division, Meteorological Office) described the operation of ocean weather ships and Mr. J. Paton gave an address on the optical properties of the atmosphere.

Capt. Frankcom outlined the story of the development of the ocean weather ships, which commenced work in August 1947, and gave a full description illustrated by lantern slides of their functions and equipment. It was interesting to learn that in addition to their main work of meteorological observation and navigational assistance to transatlantic aviation they are making observations of marine biology and are to collaborate in seismological research. Capt. Frankcom then referred to the difficult conditions in which work has often to be carried on. On some voyages during the winter the wind had never fallen below force 6. Nevertheless no surface observations had been missed and upper air observations, in spite of the extreme difficulties of launching the balloons in strong winds, had been made in winds up to force 10. On only three occasions had ships left their station and then to land sick men.

Capt. Frankcom concluded by emphasising the close and cordial collaboration which existed on the ships between the navigating, meteorological and signals staffs.

He was followed by Captain Ford, commander of the *Weather Recorder* who, speaking on behalf of the Senior Meteorological Officer of his ship, gave a vivid impression of the difficulties of launching balloons 8 ft. in diameter and of plotting synoptic charts during the winter gales when the ships, though very seaworthy, were known to roll through an angle of 55°.

Mr. Paton's address on the optical properties of the atmosphere was illustrated by beautiful Kodachrome slides. These brought out very vividly the relative darkness of the space between the primary and secondary rainbows, the difference between the blue colour of distant hills and the golden colour of distant clouds, and the twilight arch on the eastern sky due to the earth's shadow. An interesting point, dwelt on at some length by Mr. Paton, was that our estimation of the distance of distant dark objects depends on their blueness caused by scattering by the intervening air and when this is small, as it is in the pure air at great heights, distances are very much underestimated.

In the course of the discussion which followed Dr. Dobson said recent work showed that ice crystals at very low temperatures could form in a cubic shape which would produce a 9° halo. Prof. Sheppard said when in the Arctic he had been much impressed by the extreme profusion of refraction phenomena and asked why they were less frequently seen in Great Britain. Mr. Paton said they were there just the same but were blotted out by the greater glare of the sun. They could be seen by wearing dark glasses. Dr. Ramanathan said he had observed a blue flash in the sun setting over the Indian Ocean in April when there was super-refraction of light rays in the hot dry air blowing off India.

LETTERS TO THE EDITOR

Low-level condensation trails

At 1100 G.M.T. on March 8, a Meteor IV aircraft from Horsham St. Faith, near Norwich, formed non-persistent vapour trails whilst making a high-speed low-level run across the aerodrome. The following account has been compiled with the help of the pilot, F/Lt. R. Baelz, D.F.C., and F/Lt. J. Bowring, Engineer Officer.

The aircraft, whilst flying on a north-easterly heading at 3,000 ft., went into a shallow dive and then flew level across the aerodrome at an estimated height of 300–400 ft. During the dive the true airspeed increased to 580 m.p.h. and this speed was maintained in level flight.

During the shallow dive nothing unusual was noticed, but whilst in level flight the outer two-thirds of the wings became obscured by white vapour which formed on the upper surface of the wings slightly back from the leading edge. The vapour formation did not persist for any distance behind the wings and was most dense near the wing tips. Although it was the outer portions of the wings which were mainly affected, there was a tendency for vapour to form along the wing right up to the fuselage. The vapour formation gradually ceased as the aircraft went into a climb and the dispersal of the trail was marked by a change in colour from white to blue.

The synoptic situation prevailing over East Anglia at the time was that of a moist south-westerly airstream in an open warm sector to the rear of a warm front which had passed through the area during the early morning. Weather was cloudy with a thin sheet of medium cloud, base above 15,000 ft., which gradually merged into cirrostratus. There was little or no low cloud in the vicinity at the time, although low stratus cloud was rather extensive in other parts of England and patches at 800 ft. were still persisting at 1200 G.M.T. at West Raynham, where temperature was a few degrees lower than at Horsham St. Faith. The 1100 G.M.T. surface temperature and humidity at Horsham St. Faith were estimated to be 55°F. and 80 per cent. (1200 G.M.T. values: 57·0°F. and 76 per cent.). An examination of the Downham Market upper air ascents for 0800 and 1400 G.M.T. gave the probable temperature and humidity at 350 ft. as 54°F. and 80 per cent.

The formation of low-level wing-tip trails by a Meteor IV aircraft, under suitable conditions of temperature and humidity might be expected, as its span loading of about 500 lb./ft. (approximately three times greater than that of a Spitfire) combined with the rectangular form of the wing tips, would cause fairly intense persistent vortices to be shed by the wing tips. However, the formation of vapour trails over the general upper surfaces of the wings is rather unusual, especially in straight and level flight, as the pressure reduction responsible for adiabatic cooling and resultant condensation would be effective only while the air is actually passing over the wing surface and this, in view of the high speeds involved, would correspond to a period of 1/70 sec. only. In addition, when flying at really high speeds the leading edges undergo a considerable rise in temperature and this heating effect should tend to prevent condensation.

Stradishall, March 22, 1948 T. L. HUNT

Is a general term necessary for instruments measuring meteorological elements in the free atmosphere ?

Looking over the literature of aerological measuring techniques, one is struck by the various words given for what we imagine today as a radio-sonde. Below is an anthology of word constructions found in present literature :

English :	French :
Radio-meteorograph	Météorographe émetteur de T.S.F.
Robot weather observer	Radiométéorographe
Radio balloon	Radiotélémètre
Radio-sound	Radiosonde
Radio-sonde	

German :

Funkentelegraphisch fernmeldender Registrierballon-Meteorograph
Telemeteorograph
Radiometeorograph
Fernmeldemeteorograph
Wettersonde
Radiosonde

Similar terms can be found in the Italian, Spanish, Dutch, Finnish, etc. languages. Radio-sonde or the corresponding translations have come into use more and more, but nowhere is there given a satisfactory definition of the term. In principle, " radio-sonde " is understood to mean an aerological device transmitting by wireless the most important aerological elements : pressure, temperature and humidity (formerly recorded by meteorographs) from a balloon to a ground-receiving station. The following examples make evident the insufficiency of this definition. Radio-sondes have been constructed which measure only the temperature, the pressure being calculated from the transmitted temperatures and the height of the balloon measured by means of theodolites. And also there are radio-sondes transmitting not only pressure, temperature and humidity but height and thickness of clouds and these may also be used, by new methods, for wind measurement. With the same right we may give the name radio-sonde to an instrument constructed only for wind measurement by radio, since there is no fundamental difference between the meteorological importance of pressure, temperature, humidity and wind. Similarly the passive reflectors used for wind measurement by radar without transmitter below the balloon could be named " radio-sondes ", but nobody is willing to do so. Further development may also give us " radio-sondes " transmitting pressure, temperature, humidity and other aerological elements without transmitter but by passive reflectors.

Therefore I suggest the introduction of the word " aerosonde ", with the definition " instrument or device to sound the atmosphere ". The isolated term is rather unimportant for general use but it can be made into a precise statement by corresponding additions. The method of transmission (mechanical, optical, direct or indirect by wireless means or in a still unknown manner) is of no importance. The word " aerosonde " has been so chosen as to be intelligible in all languages by a literal translation. Special forms of the instrument can be marked by additional terms, e.g. an instrument for the measurement of the standard combination : pressure, temperature and humidity can be named " temp-aerosonde " ; a device for wind measurements : " wind-aerosonde ", etc. Instruments to measure other meteorological elements may be named in the same way : " turbulence-aerosonde ", " insolation-aerosonde ", etc.

G. LOESER

(23) *Meppen-Ems, British Zone, Germany, December* 11, 1947.

NOTES AND NEWS

A new kit for climatological inspectors

Inspectors' kits are used by officers of the Meteorological Office when visiting observing stations to carry out an inspection. The existing Mk. IV outfit has frequently been adversely criticised because of its excessive weight, and the possibility of introducing an improved kit was accordingly considered in

January, 1946 before ordering more to meet the needs of the post-war inspection programme. The new outfit is known as the Inspector's Climatological Kit Mk. V.

In the design everything possible was done to keep the weight down to a minimum with the result that the new kit weighs less than 10 lb. as compared with the 13 lb. of the Mk. IV. Consideration was also given to cost and durability. The chief feature of the Mk. V kit is that the wooden box has been replaced by a canvas bag with leather fastening straps attached to a covering flap. An additional leather strap is also provided so that the bag can be slung over the shoulders.

It had been suggested that a leather case would be better than a wooden box, but it was found that the saving in weight would not have been so great as with the canvas bag and the cost would have been much greater. With a leather case, compartments are desirable for holding the various instruments and tools and it is very difficult nowadays to obtain leather goods to a new design especially when the numbers involved are small.

The bag and contents are illustrated in the photograph on the opposite page. The main changes from earlier outfits are as follows:—

(*a*) The rain-measure is graduated for a rain-gauge with funnel of 5-in. diameter. Two sets of graduations are provided, one reading in inches of rain up to 0·50 in. and one in millimetres of rain up to 10 mm. It is safely housed in a wooden box padded with sponge rubber and with hinged lid secured by two leather straps. The box also has a compartment to carry a bottle of oil.

(*b*) For checking the diameter of the rim of the rain-gauge callipers in the shape of a rule with a travelling vernier is supplied. Readings to 0·01 in. can be obtained.

(*c*) A spanner hook consisting of a square bar of tool steel with semi-circular hook to embrace the several adjusting screws of the sunshine recorder is provided.

(*d*) The sunshine sphere centering gauge is housed in a stout wooden box.

The whole kit is very compact, having dimensions 14 in. × 9 in. × 7 in.

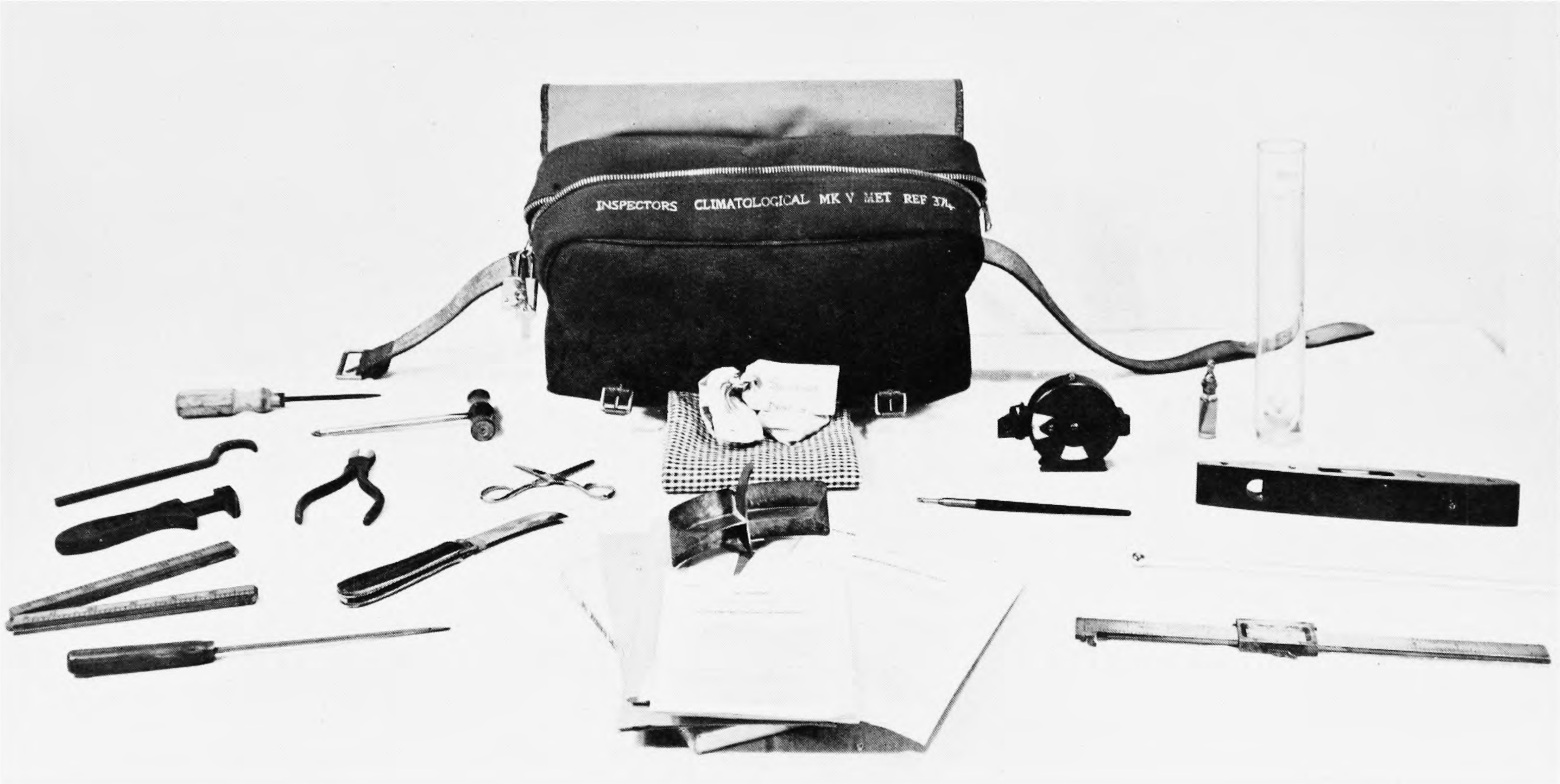
Mk. V kits were first used by inspectors in 1947 and, on the whole, they have proved to be satisfactory. The chief complaint is that all the tools are wrapped up in the duster which is less convenient than having them in separate compartments. It is considered that the saving in weight and cost more than outweigh this disadvantage. Some of the Mk. IV kits are still available for inspectors who prefer to use them.

This work was carried out in the Instruments Branch of the Meteorological Office at Harrow.

H. L. PACE

Stonyhurst College Observatory

In addition to considerable work in astronomy and geophysics, meteorological records covering a hundred years were completed at Stonyhurst College before Father F. J. Rowland retired at the end of 1947. Founded in 1838 the Observatory has been staffed and maintained by the Society of Jesus, under Directors including Fathers S. J. Perry, A. L. Cortie, E. D. O'Connor and F. J. Rowland. The meteorological results have been published (with the


INSPECTORS CLIMATOLOGICAL MK V MET REF 374

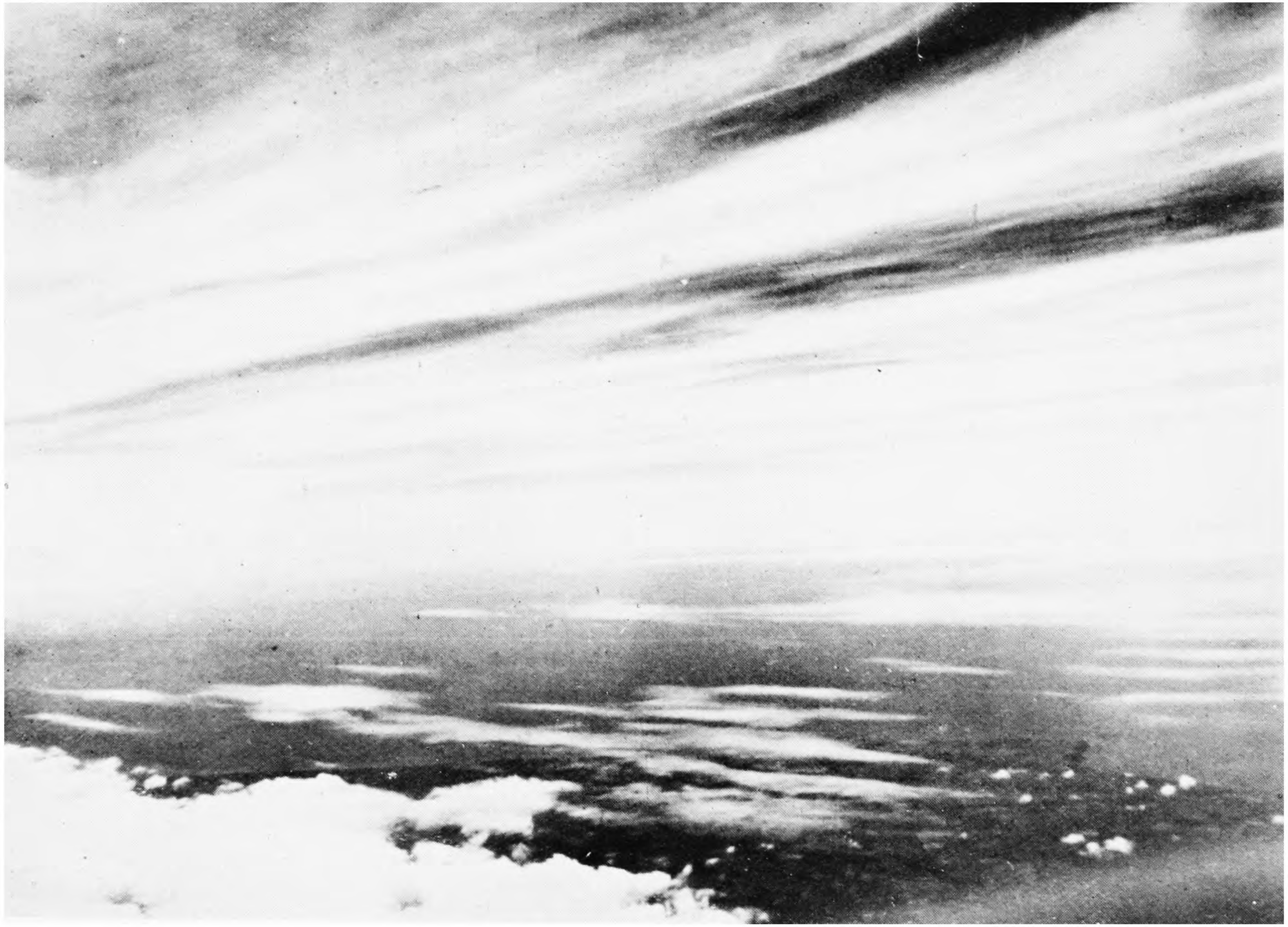
CLIMATOLOGICAL INSPECTOR'S KIT, MK. V

Canvas bag with straps

Screwdriver, gimlet,
hook spanner, pliers, scissors,
adjustable spanner, clasp knife,
boxwood rule, screwdriver,

Screws, nails, duster,
centering gauge,
publications,
N.P.L. certificate,

Prismatic compass and clinometer,
clock oil, rain measure,
writing diamond, spirit level,
inspector's thermometer,
rain-gauge calipers.



Photograph by R.A.F.

IMMEDIATELY BEHIND A WEAK WARM FRONT

Cirrostratus and stratocumulus associated with a warm front lying north-north-west to south-south-east over Cumberland; patches of low stratus in the warm air drifting over the Irish Sea. Photograph taken looking south-south-west from 13,000 ft. over 54°30′N. 3°30′W. at 1230, July 30, 1945.

geophysical and solar observations) in annual reports up to that for 1943, as well as in various publications of the Meteorological Office. A summary of the records was included in the *Weekly Weather Report* from 1878 and the *Monthly Weather Report* from 1884.

In 1867 the Meteorological Committee of the Royal Society selected Stonyhurst as one of the seven principal stations, along with Kew, Falmouth, Glasgow, Aberdeen, Armagh and Valentia, each equipped with self-recording instruments of pressure, temperature, wind, sunshine and rain. It is interesting to recall that the object in establishing these seven land stations was " first, to give accurate data for a discussion of the law of storms and weather changes, and secondly, to ascertain meteorological constants, thereby performing with great precision for the land stations that which is accomplished with moderate precision by the Ocean Meteorology Branch for the entire ocean". For many years therefore these stations formed the basis of British meteorology.

The long rainfall record at Stonyhurst has also proved useful with other stations in defining the changes experienced over England during the last century. The temperature record was used by Mr. Gordon Manley in his Presidential address entitled " Temperature Trend in Lancashire, 1753–1945 "*, showing the tendency for January and the year to have become on the whole somewhat warmer within the period of the Stonyhurst record.

The continuation of the records during the war was particularly difficult, especially when the observer, Mr. W. Brown, was called to the Forces. In spite of the advancing years and failing health of Father Rowland the records were, however, maintained until his retirement. It is satisfactory to find that Father J. Lawrence is arranging to continue the main records, although observations are being confined to 0900 G.M.T. and some of the instruments are being moved in order to simplify the work.

J. GLASSPOOLE

A new periodical on bioclimatology

We welcome the appearance of the new periodical *Wetter und Leben* (Zeitschrift für Praktische Bioklimatologie), organ of the Austrian Bioclimatological Society. Besides publishing articles it is planned to review all Austrian and as many foreign publications as possible on bioclimatology.

The first number contains articles on the weather of the abnormal year 1947, secular variations in the level of the Danube at Vienna, effects of weather on hay-fever and bioclimatic observations on the pine bark beetle; minor contributions include reports of bioclimatic discussions held at the Zentralanstalt für Meteorologie und Geodynamik, a report on the weather of March 1948 in Austria and nine reviews. It contains 28 octavo pages.

The editor is Dr. F. Sauberer, Wien, XIX., Hohe Warte 38, and the yearly subscription price is given as 24 Swiss francs.

OBITUARY

Professor Filippo Eredia.—With the death of Professor Eredia on February 14, 1948, Italy loses one of her leading meteorologists. Professor Eredia was born at Catania on November 10, 1877. His first scientific post was at the Astrophysical

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Quart. J. R. met. Soc., London,* **72, 1946, p. 1.

Observatory of Catania where he became an assistant in 1903, but in 1904 he transferred to the Central Meteorological Office in Rome. In 1925 he was appointed Geophysical Director of the newly formed Ufficio Presagi of the Ministry of Aeronautics which post he held until 1937. From 1937 to 1945 he was Lecturer in Meteorology at the University of Rome and Director of the Aerological Institute of the University.

Eredia was a prolific worker in many branches of meteorology, the number of separate articles by him in the library of the Meteorological Office amounting to over 200. They include papers on the climatology of many places in Italy and north Africa, summaries and discussions of upper wind and temperature observations, especially those made by the aerological station at Vigna di Valle, climatic effects on the incidence of disease, aviation meteorology, instruments and the teaching of meteorology. In addition to these articles he wrote a treatise on meteorological instruments (two editions, 1916 and 1936), a general text-book of meteorology (1942), and a work on the meteorology and aerology of the North Atlantic Ocean (1935).

Eridia was as well known internationally as in Italy. He became a member of the International Commission for the *Réseau Mondial* in 1919, and later served on the Commissions for Aerology, Climatology, Synoptic Weather and Agricultural Meteorology. He was secretary of the meteorological section of the International Union of Geodesy and Geophysics from 1922 to 1927.

When in 1933 a squadron of Italian seaplanes flew to Chicago and back Eredia was in charge of the meteorological arrangements and provided forecasts for the Atlantic crossings from an office at Londonderry.

He held the Gold Medal of the Italian Society for Climatology and the silver medal of the Italian Geographical Society.

REVIEWS

World Weather Records 1931-40 (continued from volumes 79 and 90), prepared in co-operation with the various official weather services and observatories of the world, assembled and arranged for publication by H. Helm Clayton* and Frances L. Clayton. *Smithson. misc. Coll., Washington, D.C.,* **105**, 1947, pp. x +646.

At the International Meteorological Conference held at Utrecht in September 1923 the following resolution was passed :—

" 13. . . . . . .The Conference thinks, that publication of long and homogeneous series of observations in the form of monthly means of pressure, temperature and rainfall would be of the highest importance for the study of the general circulation of the atmosphere . . . . . . It proposes that the various meteorological institutes should establish such series up to the year 1920 . . . . . . "

To meet the need expressed in this resolution the Smithsonian Institute, with the aid of a generous grant from Mr. John A. Roebling, published in 1927 a book entitled " World Weather Records " as volume 79 of their series of *Smithsonian Miscellaneous Collections.* This volume, which was arranged for publication by the late Mr. H. Helm Clayton, contained monthly averages of pressure, temperature and precipitation for 385 land stations. With a few exceptions the tables for each station covered at least the 20 years 1901-20, and for some stations the period covered was much longer. In 1934 the second volume of " World Weather Records " was published containing the data for 1921-30. The International Meteorological Organization expressed its appreciation of the services rendered by Mr. Clayton and Mr. Roebling in the production of these two volumes in a resolution passed by the Conference of Directors held at Warsaw in 1935. In 1947 the third volume appeared, giving the data for 1931-40. Meteorology is again indebted to Mr. Roebling for the funds to publish such a wealth of information in a handy form.

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* Mr. H. H. Clayton died in October 1946.

The arrangement follows that of previous volumes. Part I contains the monthly and annual means of pressure, temperature and rainfall at some 420 land stations with the 10-year averages. These tables are preceded, as in the previous volumes, by notes on the stations. On account of the outbreak of war many of the European services (including Great Britain) were unable to co-operate in the preparation of these tables by sending their data. It was possible, however, to extract most of the data for these countries up to 1937, and in some cases to 1939, from official publications which were available in the libraries of Harvard University and Blue Hill Observatory. The British data were copied from the *Monthly Weather Report* and from the " Climatic Table for the British Empire " published for each month in this magazine up to November 1939 which appeared in the number for June 1940.

The data thus collected are not in all cases quite comparable without adjustment with those of the previous volumes. For example, pressure is given at a mean sea level for some stations for which it was previously given at station level. At other stations small differences are introduced by the fact that monthly means have been computed from a different combination of hours from those in the previous volumes.

Among the stations for which pressures are given at mean sea level are Freetown (Sierra Leone) and St. Helena. Unfortunately, on account of incorrect estimates of their heights, the sea-level pressures published for these stations, which were copied from the " Climatic Table for the British Empire ", are not correct. The values for Freetown up to July 1935 (when the true height was ascertained) should be corrected by—1·6 mb. ; the sea-level pressures for St. Helena require the following corrections : +2·3 mb. to August 1933, +3 mb. from September 1933 to the end of 1937, −0·7 mb. from January 1938 to May 1939, and +3 mb. from June 1939 to the end of 1940.

It is, perhaps, worth while to mention a small point here as it may confuse some users of the tables. In some cases, when the site of a station has changed, the pressure means have been reduced to the level of the old site to keep them consistent with values published in the previous volumes. Where this has been done the old height has been quoted with the result that the published height is not the true height of the station during 1931-40, the period concerned.

Part II which appeared for the first time in the second volume under the title " Ocean and sea-level pressures " is again included. In this volume sea-level pressures are given at the intersections of the parallels and meridians at 10° intervals over the whole northern hemsphere, covering land areas as well as the oceans. For these 289 positions (including the north pole) monthly and annual means are given, with some exceptions, from 1929 to 1939. These means have been published by permission of the Chief of the United States Weather Bureau. They were obtained by reading the pressures at the 10° intersections from the charts published in 1944 by the Weather Bureau entitled " Historical weather maps, northern hemisphere sea level " which are synoptic charts for approximately 1300 G.M.T. each day. It is considered that, except north of 70°N. and in some areas south of 20°N. where observations are scanty, the pressure means obtained in this way are accurate to about ½ mb. Their agreement with the means for nearby land stations, where observations are as a rule made three or more times a day, is not, however, always quite so close and means for some individual months differ by more than a millibar.

Part III, " Additional data ", contains tables of pressure, temperature and rainfall mostly up to 1930, which were received too late for inclusion in the previous volume. Included also in this section are two groups of rainfall tables. In the first group are tables for the banana and sugar areas of the Caribbean Sea, which were supplied by the United Fruit Company of Boston, Mass. These tables do not refer to individual stations but give monthly and annual averages of several stations in each of the areas during the years 1931-40. There is no information about the positions of the individual gauges or as to whether their exposures conform to standard. The second group constitutes a very useful summary of the precipitation in each state or section of the United States during the 55 years 1886-1940 : the data are arranged seasonally as percentages of the normal.

Appearing for the first time in this volume is an appendix giving lake and river levels. The lakes included are Victoria, Michigan and Titicaca (Bolivia), and the rivers Nile and Plate. The valuable series for Lake Michigan covers 84 years (1860-1943) of monthly means.

As in the previous volumes, a table of monthly sunspot numbers for the ten years is included.

In all, there are 562 pages of Tables. They are clearly printed on good paper which should be able to stand up to constant use.

E. H. GEAKE

Remarks on some classes of local winds, a contribution to dynamical climatology, by F. H. Schmidt. Koninlijk Nederlandsch Meteorologisch Instituut, De Bilt. No. 125 Mededelingen en Verhandelingen, Serie B, Deel 1, No. 5. Size: 12¼ in. × 8¾ in. pp. 10. *Illus.* 's-Gravenhage, 1947. Price 0.75 florins.

This study deals with the classification of a number of well known " local " winds, such as the bora, föhn, etc. Dr. Schmidt's classification is not the customary geographical one. Instead he has put forward a scheme based upon the underlying physical and meteorological conditions which give rise to these winds. He considers that by so doing, these winds can the more easily and logically be identified and appreciated, and a contribution made to the dynamical climatology of the regions where these winds occur. Dr. Schmidt concludes that local winds are due to four main causes :—

A. To the field of pressure.
B. To the relief of the earth's surface.
C. To air mass.
D. To the passage of a front.

Subsidiary causes give rise to a number of subdivisions. Thus Cause A is subdivided according to (*a*) the force, (*b*) the direction and (*c*) the frequency of the wind, Cause B according as the topography induces the descent of (*a*) warm, or (*b*) cold air, or (*c*) the acceleration of the air in a valley, Cause C according-ing as the air mass constituting the wind is (*a*) arctic, (*b*) polar, (*c*) tropical or (*d*) equatorial, while Cause D is subdivided according as the winds are associated with the passage of (*a*) a warm or (*b*) a cold front. Local winds may therefore be ascribed to twelve distinct causes.

As instances of his classification, Dr. Schmidt includes the föhn on the north side of the Alps and on the coasts of Greenland, the autan of central France, the chinook winds of the Rocky Mountains and the zonda on the east side of the Andes under Class B(*a*); the bora, the bohorok, the local mistral, the bise in the French Alps, the kossava of the Balkans and the polake of Bohemia in Class B(*b*); the tramontana near Perpignan and the willy-waws at the south point of South America in Class B(*c*). Examples of the winds of Class C(*c*) are the sciroco, the khamsin, the brickfielder of Australia and the simoon.

If account be taken of the effect of all the thermal and dynamical influences of the underlying surface on the moving air in contact with it, it is possible to obtain a very large number of classes of air. The author is therefore to be congratulated in steering a middle course between an excessive complexity and over simplification. The inclusion of two classes to take account of local winds at the passage of a front—and the author is unable to find examples of local winds originating at the passage of a warm front—does appear to be a refinement which is not altogether necessary. The text has a number of synoptic charts—a very useful addition to the work.

J. E. BELASCO

NEWS IN BRIEF

A new polar institute (Norske Polarinstitutt) was established in Norway on March 1, 1948, with Dr. H. U. Sverdrup as the first Director.

Continuing and expanding the activity formerly under the control of Norges Svalbard- og Ishavs-undersøkelser, it will provide facilities for numerous scientific workers to visit Svalbard (i.e. all Norwegian polar territory including Spitsbergen, Bear Island, etc.) and east Greenland; it will establish aids for navigation and weather stations. The institute will work under the Department of Industry of the Norwegian Government but will be connected with the Universities of Oslo and Bergen.

Dr. Sverdrup, who has had a distinguished career as arctic explorer, oceanographer and mathematician, has written many books and papers on oceanography including " Oceanography for meteorologists ".

WEATHER OF JUNE 1948

During most of the month unsettled conditions prevailed, with depressions or troughs of low pressure crossing the British Isles. There was, however, an interval from the 9th to the 13th during which a wedge of relatively high pressure extended southwards over these islands from an Arctic anticyclone, and another such interval from the 23rd to the 27th when there was a ridge of relatively high pressure connecting anticyclones centred north and south-west of the British Isles.

Mean pressure for the month was below 1010 mb. in Labrador, to the south of Iceland and from the Gulf of Bothnia to the north-west shore of the Black Sea, and above 1020 mb. from the southern part of the Bay of Biscay nearly to Bermuda. It was rather above the average in south-west Europe and the Azores, and over the Greenland sea but below the average from the eastern part of the United States across the British Isles to Russia, the deficiency being about 5 mb. in north-eastern Britain.

The weather over the British Isles was unsettled, wet, dull and rather cool.

Unsettled weather prevailed during the first eight days with depressions or troughs of low pressure passing over the British Isles. Rain, heavy at times, occurred frequently and gales were reported locally on the 2nd, 3rd and 5th and more generally on the 6th. Thunderstorms occurred at numerous places in England on the 1st and in Scotland on the 8th. Subsequently a wedge of high pressure moved slowly east over the British Isles and a spell of less unsettled weather prevailed over much of the country until the 13th. On that day pressure was almost uniform and conditions on the 13th and 14th were warm and thundery with temperature rising to about 80°F. at a number of places. Thereafter the weather again became unsettled and cool, with frequent rain and thunderstorms. During the 23rd the Azores anticyclone spread north-east and a spell of fairer weather occurred in eastern districts from the 24th to 26th. In the closing days pressure was low over southern Scandinavia and high to the west of the British Isles; cool, showery weather occurred and rather widespread thunderstorms were reported on the 28th.

Mean temperature was about average or somewhat below. Warm days occurred on the 8th, 13th, 14th and 26th. The coolest spells were the 1st–6th and 27th–30th. On the whole rainfall was very excessive; less than the average occurred, however, in the extreme north-west of Scotland and over fairly large areas in the south of England. More than twice the average occurred over much of the country extending south from the Moray Firth to north Lancashire and east over the North and East Ridings of Yorkshire as well as in west Wales. More than three times the average occurred in the neighbourhood of Balmoral and Keswick. Among the larger falls in 24 hours were 3.00 in. at Borrowdale on the 2nd and 2·52 in. at Borrowdale and 2.48 in. at Treherbert (Glamorgan) on the 6th. During a severe thunderstorm in the London area on the 14th, 2.41 in. was measured at East Ham. Sunshine was appreciably below the average.

The general character of the weather is shown by the following table:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	83	36	−0·4	151	+6	82	33
Scotland	79	31	0·0	181	+4	77	27
Northern Ireland ..	74	36	−0·5	139	+4	79	27

RAINFALL OF JUNE 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	2·11	104	*Glam.*	Cardiff, Penylan ..	3·59	143
Kent	Folkestone, Cherry Gdns.	1·89	95	*Pemb.*	St. Ann's Head ..	3·03	145
,,	Edenbridge, Falconhurst	3·42	155	*Card.*	Aberystwyth	5·39	220
Sussex	Compton, Compton Ho.	3·17	127	*Radnor*	Bir. W. W., Tyrmynydd	5·84	179
,,	Worthing, Beach Ho. Pk.	1·42	81	*Mont.*	Lake Vyrnwy	8·13	250
Hants.	Ventnor, Roy. Nat. Hos.	1·27	69	*Mer.*	Blaenau Festiniog ..	13·89	214
,,	Bournemouth	2·36	117	*Carn.*	Llandudno	3·30	174
,,	Sherborne St. John ..	2·20	103	*Angl.*	Llanerchymedd ..	3·46	146
Herts.	Royston, Therfield Rec.	3·68	164	*I. Man.*	Douglas, Boro' Cem. ..	5·82	240
Bucks.	Slough, Upton ..	2·48	120	*Wigtown*	Port William, Monreith	4·19	178
Oxford	Oxford, Radcliffe ..	2·11	94	*Dumf.*	Dumfries, Crichton R.I.	6·00	237
N'hant.	Wellingboro', Swanspool	2·99	142	,,	Eskdalemuir Obsy. ..	6·93	220
Essex	Shoeburyness	1·64	93	*Roxb.*	Kelso, Floors	4·39	208
Suffolk	Campsea Ashe, High Ho.	3·15	167	*Peebles.*	Stobo Castle	4·90	209
,,	Lowestoft Sec. School ..	3·40	188	*Berwick*	Marchmont House ..	3·57	155
,,	Bury St. Ed., Westley H.	2·66	127	*E. Loth.*	North Berwick Res. ..	2·47	149
Norfolk	Sandringham Ho. Gdns.	3·11	143	*Midl'n.*	Edinburgh, Blackf'd. H.	4·02	201
Wilts.	Bishops Cannings ..	2·31	95	*Lanark*	Hamilton W. W., T'nhill	5·90	268
Dorset	Creech Grange.. ..	2·76	120	*Ayr*	Colmonell, Knockdolian	4·15	164
,,	Beaminster, East St. ..	1·83	81	,,	Glen Afton, Ayr San. ..	6·32	211
Devon	Teignmouth, Den Gdns.	1·67	87	*Bute*	Rothesay, Ardencraig ..	5·16	168
,,	Cullompton	2·61	123	*Argyll*	L. Sunart, Glenborrodale	5·15	160
,,	Barnstaple, N. Dev. Ath.	1·88	84	,,	Poltalloch	3·87	127
,,	Okehampton, Uplands	2·57	93	,,	Inveraray Castle ..	7·32	185
Cornwall	Bude School House ..	2·71	135	,,	Islay, Eallabus ..	3·34	128
,,	Penzance, Morrab Gdns.	2·37	107	,,	Tiree	3·78	148
,,	St. Austell, Trevarna ..	2·40	92	*Kinross*	Loch Leven Sluice ..	4·93	225
,,	Scilly, Tresco Abbey ..	1·70	98	*Fife*	Leuchars Airfield ..	3·44	206
Glos.	Cirencester	2·68	112	*Perth*	Loch Dhu	6·30	151
Salop	Church Stretton ..	3·08	121	,,	Crieff, Strathearn Hyd.	4·80	182
,,	Cheswardine Hall ..	4·11	168	,,	Blair Castle Gardens ..	..	..
Staffs.	Leek, Wall Grange P.S.	4·69	180	*Angus*	Montrose, Sunnyside ..	3·79	228
Worcs.	Malvern, Free Library	2·15	93	*Aberd.*	Balmoral Castle Gdns...	5·34	314
Warwick	Birmingham, Edgbaston	3·69	159	,,	Dyce, Craibstone ..	5·07	271
Leics.	Thornton Reservoir ..	2·25	104	,,	Fyvie Castle	5·22	249
Lincs.	Boston, Skirbeck ..	3·48	191	*Moray*	Gordon Castle	4·88	239
,,	Skegness, Marine Gdns.	..	..	*Nairn*	Nairn, Achareidh ..	4·03	228
Notts.	Mansfield, Carr Bank	2·56	113	*Inv's*	Loch Ness, Foyers ..	4·86	219
Ches.	Bidston Observatory ..	3·06	139	,,	Glenquoich	7·29	148
Lancs.	Manchester, Whit. Park	4·42	167	,,	Fort William, Teviot ..	5·53	156
,,	Stonyhurst College ..	6·87	224	,,	Skye, Duntuilm ..	3·66	141
,,	Blackpool	4·48	205	*R. & C.*	Ullapool	2·24	98
Yorks.	Wakefield, Clarence Pk.	2·44	113	,,	Applecross Gardens ..	4·69	164
,,	Hull, Pearson Park ..	4·69	228	,,	Achnashellach	5·64	150
,,	Felixkirk, Mt. St. John	5·58	255	,,	Stornoway Airfield ..	2·16	98
,,	York Museum	3·61	174	*Suth.*	Lairg	3·19	153
,,	Scarborough	3·75	204	,,	Loch More, Achfary ..	3·45	93
,,	Middlesbrough.. ..	4·80	254	*Caith.*	Wick Airfield	2·87	159
,,	Baldersdale, Hury Res.	4·08	173	*Shet.*	Lerwick Observatory ..	1·90	106
Norl'd	Newcastle, Leazes Pk.	3·18	151	*Ferm.*	Crom Castle	3·96	146
,,	Bellingham, High Green	4·33	188	*Armagh*	Armagh Observatory ..	4·33	172
,,	Lilburn, Tower Gdns...	3·77	182	*Down*	Seaforde	2·86	104
Cumb.	Geltsdale	4·81	178	*Antrim*	Aldergrove Airfield ..	3·42	142
,,	Keswick, High Hill ..	9·12	313	,,	Ballymena, Harryville..	4·26	146
,,	Ravenglass, The Grove	5·33	204	*Lon.*	Garvagh, Moneydig ..	3·78	149
Mon.	Abergavenny, Larchfield	3·50	143	,,	Londonderry, Creggan	3·78	134
Glam.	Ystalyfera, Wern House	7·36	195	*Tyrone*	Omagh, Edenfel ..	3·41	121

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, FEBRUARY 1948

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1021·8	+6·8	58	23	46·0	36·7	41·3	+0·6	38·0	79	7·9	1·43	−0·11	12	2·4	24
Gibraltar	1020·3	+0·3	73	48	65·1	54·3	59·7	+3·9	55·3	85	6·2	2·58	—	9	5·8	54
Malta	1017·3	+1·2	67	44	59·2	50·1	54·7	−0·6	52·5	73	5·3	1·30	—	8	6·6	61
St. Helena	1014·7	0·0	80	60	74·4	62·1	68·3	+3·0	62·3	98	8·2	3·90	+1·16	18	—	—
Freetown, Sierra Leone	1010·7	+1·4	91	74	85·1	75·7	80·4	−0·3	75·3	81	5·2	0·00	−0·30	0	7·5	63
Lagos, Nigeria ..	1010·5	+0·8	92	63	90·4	71·1	80·7	−1·8	75·9	85	6·8	2·84	—	4	6·5	55
Kaduna, Nigeria ..	1009·9	—	98	55	91·2	62·3	76·7	−1·0	56·5	19	2·3	0·00	−0·02	0	9·3	79
Chileka, Nyasaland ..	1013·4	+1·4	88	65	82·2	67·6	74·9	+0·7	69·4	79	7·7	11·92	+3·84	20	4·6	37
Lusaka, Rhodesia ..	1011·6	+1·3	86	60	79·1	62·7	70·9	+0·2	65·0	84	8·1	5·48	−3·14	18	5·5	—
Salisbury, Rhodesia ..	1012·6	+1·4	83	55	78·1	60·5	69·3	+0·4	62·7	74	6·5	6·57	−0·32	19	6·1	48
Cape Town ..	1013·9	+0·5	102	55	82·1	62·5	72·3	+2·0	59·8	64	3·9	0·13	−0·45	5	—	—
Germiston, South Africa	1013·5	—	83	45	75·5	56·0	65·7	—	57·3	75	4·1	1·84	—	9	8·1	63
Mauritius	1012·2	+1·4	95	65	89·8	71·8	80·8	+1·5	73·6	76	3·7	2·65	−4·86	13	10·0	78
Calcutta, Alipore Obsy.	1013·3	−0·2	94	53	84·5	63·0	73·7	+2·5	64·0	85	3·1	1·47	+0·48	5	8·6	75
Bombay	1012·3	−0·4	91	64	84·9	69·9	77·4	+1·7	67·1	77	1·4	0·00	−0·03	0	9·6	84
Madras	1012·7	−0·2	94	67	88·1	71·3	79·7	+2·0	72·7	86	2·8	0·03	−0·27	1	10·4	89
Colombo, Ceylon ..	1011·9	+1·1	91	69	87·6	72·5	80·1	−0·3	72·5	90	4·8	0·17	−1·77	2	9·2	77
Singapore	1010·6	+0·4	91	72	86·1	73·7	79·9	−0·3	75·1	83	7·8	5·77	−0·85	18	—	—
Hongkong	1018·4	−0·2	78	46	67·4	58·4	62·9	+3·8	59·8	87	—	0·17	−1·66	16	3·0	26
Sydney, N.S.W. ..	1013·2	−0·7	94	59	79·3	67·3	73·3	+2·0	68·4	72	6·4	2·80	−1·40	12	6·8	50
Melbourne	1011·7	−2·8	104	53	79·9	59·2	69·5	−1·9	60·5	58	6·4	1·95	+0·24	9	7·0	52
Adelaide	1013·1	−1·2	106	51	82·3	60·9	71·6	−2·4	59·4	42	5·5	0·22	−0·50	4	8·8	74
Perth, W. Australia ..	1011·6	−1·4	107	58	87·5	65·5	76·5	+2·4	65·6	50	2·4	0·02	−0·43	1	10·4	79
Coolgardie	1012·8	+0·4	101	50	87·6	64·2	75·9	−0·3	60·9	52	4·6	9·33	+8·48	6	—	—
Brisbane	1014·0	+1·5	91	65	83·1	68·8	75·9	−0·6	70·1	74	6·5	3·30	−3·04	13	7·3	56
Hobart, Tasmania ..																
Wellington, N.Z. ..	1016·2	+0·4	79	47	69·8	54·7	62·3	+1·1	57·9	74	7·7	2·51	+0·63	8	8·1	59
Suva, Fiji	1005·9	−1·9	86	68	83·3	74·0	78·7	−1·6	75·1	84	7·6	32·76	+22·04	21	5·3	42
Apia, Samoa ..	1007·6	−0·6	89	73	85·3	74·9	80·1	−0·2	77·4	85	9·2	22·37	+7·48	28	3·5	28
Kingston, Jamaica ..	1016·0	+0·7	92	65	88·9	68·9	78·9	+2·4	70·7	66	1·7	0·00	−0·60	0	9·3	80
Grenada, W. Indies ..	1013·8	+0·3	85	61	83·6	72·9	78·3	+1·2	72·6	78	5·6	1·34	−1·44	13	—	—
Toronto	1023·7	+5·7	52	−1	30·5	15·8	23·1	+2·0	19·8	—	6·4	3·16	+0·78	14	3·9	37
Winnipeg	1022·4	+0·6	29	−30	9·7	−8·3	0·7	+0·6	−4·2	—	5·6	0·69	−0·05	5	4·7	47
St. John, N.B. ..	1021·0	+7·1	45	−15	26·0	5·8	15·9	−4·0	9·4	—	4·7	3·33	−0·57	13	5·9	57
Victoria, B.C. ..	1016·8	+0·2	55	20	43·6	31·9	37·7	−2·8	34·4	89	7·0	6·61	+3·35	16	3·2	31

M.O. 501 AIR MINISTRY

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NIGHT-SKY RECORDER

BY N. K. JOHNSON, A. J. LANDER AND W. A. TOMS

For several years past the *Monthly Weather Report* of the Meteorological Office has given figures showing the number of hours each month during which certain circumpolar stars were visible at Greenwich and Porton. Both sets of results are obtained by means of a poleward-directed camera. In the case of Greenwich the camera shutter is opened and closed by a member of the staff, but as no staff is on duty at night at Porton, it was necessary to devise some mechanical form of shutter which would open and close itself at the correct times; this shutter is the key feature of the Porton instrument. The following account describes the shutter in some detail and gives an outline of the other essential parts of the apparatus.

External housing.—The camera proper is shielded from the weather by being mounted inside an outer housing, shown in Fig. 1, facing p. 204. The top portion of the cowl overhangs, and thus reduces the tendency for rain and snow to enter the frontal opening. The cowl can be lifted so as to afford easy access to the camera within. The lower end of the cowl is closed by a watertight metal sheet with a central aperture opposite the camera lens. The axis of the housing is, of course, directed to the celestial pole. In the latest design of instrument an open sight is provided to facilitate this operation.

The camera sits on two transverse supports, and access to the film-changing mechanism at the back is obtained through a large door at the lower end of the outer housing.

The inside of the housing is painted dead-black.

Camera.—The camera is constructed with mahogany sides and brass front and back. It is illustrated in Figs. 2 and 3. The front plate is provided with an optical glass window in line with the lens, and a large circular cover-plate which allows access to the timing device of the shutter (see Fig. 2). Behind the front plate is mounted the complete shutter mechanism which is described in the next section and is shown in Fig. 3 placed on top of the camera. The achromatic lens of 22-mm. aperture and 250-mm. focal length is situated behind the shutter.

At the back of the camera is fitted the body of a quarter-plate roll-film camera in which six additional windows have been made, enabling seven exposures to be obtained on an ordinary six-exposure film (see Fig. 3). The size of each negative is 3¼ in. × 3¼ in. (8·25 cm. × 8·25 cm.). A safety shutter is provided to permit adjustments to the shutter during day-time should this be necessary.

Shutter.—The earlier types of shutter which were tried aimed at opening and closing instantaneously. To achieve this it was necessary to have, in addition to the controlling clock, some other source of power, either electrical or mechanical, since no ordinary clock possesses sufficient power for the purpose. This arrangement also needed some form of indicator to show whether the mechanism was functioning correctly, since otherwise failure of the shutter would remain undetected until the film was developed at the end of the week.

The present design of shutter operates from the power of an ordinary daily clock as used in the standard recording instruments of the Meteorological Office. Its mode of operation can be seen from Fig. 3. The clock spindle carries the 24-hour dial A which is read against the index B. The two striking arms C and D are also carried on the clock spindle to which they are locked by the milled nut E which permits their being set to operate at selected times. In the course of their rotation, the plain ends of the striking arms engage a tooth of the eight-point star-wheel F and turn it an eighth of a revolution. The rotary shutter G consists of a circular disc containing a single aperture, and is connected to the star wheel by the 4 : 1 gear wheels of which one can be seen at H. In this way the passage of each striking arm rotates the shutter half a revolution, the first opening it and the second closing it. To prevent accidental movement of the shutter due to vibration or other cause, a light spring catch is arranged to engage the teeth of one of the gear wheels.

The shutter is in motion for about half an hour at each of the operations of opening and closing, but actually begins to admit light after about 20 minutes of action in the first case and completely covers the lens aperture after about 10 minutes in the second case. These time lags are allowed for in the setting tables.

The striking arms are set once a week and provide for the shutter being open during the period that the sun is 10 degrees below the horizon. Allowance is made for the lags just mentioned, and also for the increasing length of day during the first half of the year, which necessitates the setting being computed for the end of the week instead of the beginning. Times computed in this way are embodied in permanent setting tables.

The clock-winding key is placed at the back of the camera at J.

Method of analysing the records.—A typical starshine record is shown in Fig. 4, facing p. 205. The bright arc near the centre is the track of the Pole Star (α Ursæ Minoris), and the second brightest is that of δ Ursæ Minoris. The original negative shows about 20 additional stars within its field which embraces a circumpolar area of about 9 degrees radius. Until March 1932, the length of the Pole-Star trace only was measured, but since that date δ Ursæ Minoris has also been included in the analysis.

The measurement of the traces is carried out by means of a glass scale shown in Fig. 5. The radial lines are spaced at 15 degrees apart and therefore represent hourly intervals. The two annular markings are drawn with radii corresponding to the polar distances of the two stars to be measured and are used for centring the negative correctly on the scale. In practice it has been found convenient to build the scale into the top of a sloping desk and to illuminate it from below, the film being then laid over the scale.

The beginning and end of the starshine traces are measured, to the nearest tenth of an hour, relative to the lower edge of the film which corresponds to upper culmination, the times of upper culmination of the two stars being obtained from the *Nautical Almanac*. The analyses for each individual night in a month are drawn in the form of a chart as shown in Fig. 6, the central portion of which shows the corresponding sunshine record for each day. The gaps around sunrise and sunset correspond to the twilight intervals during which neither starshine nor sunshine recorder is working.

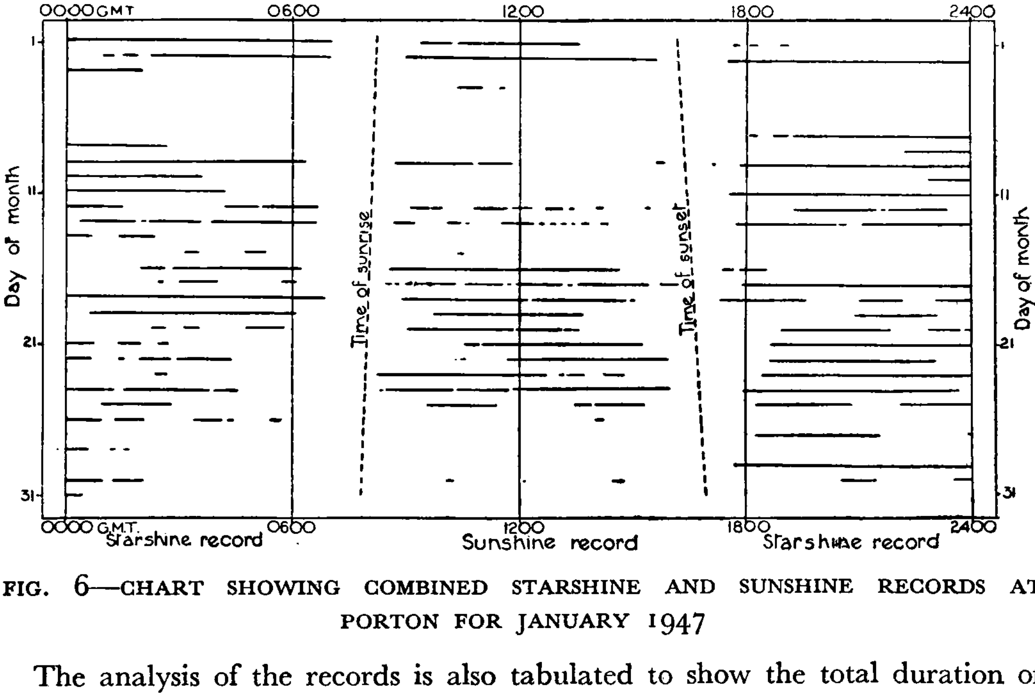

FIG. 6—CHART SHOWING COMBINED STARSHINE AND SUNSHINE RECORDS AT PORTON FOR JANUARY 1947

The analysis of the records is also tabulated to show the total duration of starshine each night. The results are summed for the month, and this total is expressed as a percentage of the total time during which the camera shutter has been open. The monthly total and percentage constitute the form in which the results are published in the *Monthly Weather Report*.

Significance and value of night-sky records.—It is unfortunate that the photographic records given by the night-sky camera do not permit a direct determination of the type of cloud present. The traces of both α and δ Ursæ Minoris are obliterated by cirrus.* Nor does there seem to be any prospect of overcoming this by adopting a large aperture lens or by any other simple means. In many cases, however, the type of cloud in the sky at night can be inferred from the observations made at 1800 and 0700. The night-sky camera and the observation log book are thus complementary. Employed in this way, the night-sky camera should prove of value in such problems as investigating the times of incidence and dispersion at night of clouds of various types—including fog.

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*Bright moonlight obliterates all star traces except those of α and δ Ursæ Minoris. It is therefore not possible, as has been suggested, to estimate the nocturnal visibility from the number of star traces recorded.

In addition to such statistical uses, the night-sky record is also valuable at meteorological research stations where investigations of an observational nature are in progress. Examples of this are given in *Geophysical Memoirs* Nos. 46 and 77, where the night-sky record was employed in selecting occasions for determining the vertical lapse rate of temperature with clear and overcast skies and for showing the time of formation of radiation fog in an investigation of the thermal processes associated with this phenomenon. Even with its known limitations, therefore, the night-sky camera should prove a valuable instrument both for collecting statistical information about the state of the sky and also in the study of radiation and other problems.

Location of night-sky recorders.—Fifteen instruments have been made and nine are now in operation at the observatories at Kew, Eskdalemuir and Lerwick, and at Church Fenton, Cambridge, Stornoway, Pembroke Dock, Rye and Aldergrove.

The remaining six instruments are to be installed at Aberdeen, Bangor, Dalwhinnie, Elmdon, Penzance and Valentia.

The above are additional to the original instruments at Greenwich and Porton, which are still in operation.

INTERGOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION

BY COMMANDER C. E. N. FRANKCOM, R.N.R.

In Geneva, in March 1948, a new international organization was born. In the Palace of Nations, delegates of 34 nations which own shipping or are actively concerned in international trade, took part in a conference convened by the United Nations Organization, the object of which was to form this new international maritime organization. The International Meteorological Organization (I.M.O.) was represented at the Conference by Commander Frankcom, President of the Maritime Commission.

It is interesting to note that, despite the essentially international nature of the shipping industry, there has never before been any permanent international shipping organization having Government status. International conferences on shipping problems—notably on Safety of Life at Sea—have been held from time to time, and a Safety of Life at Sea Convention has been in existence for many years, but there has been no permanent organization to deal with problems as they arise.

The new organization will provide the necessary machinery for co-operation between Governments in all technical matters concerning shipping engaged in international trade, especially those concerned with the efficiency of navigation and the safety of life at sea. It will also be concerned with such commercial matters as the removal of discrimination and other restrictions on shipping.

The title of the new organization, " The Intergovernmental Maritime Consultative Organization ", may not appear too felicitous, but the reasons for this choice were largely to indicate the relatively restricted nature of its activities.

The relationship between the International Meteorological Organization and this new body might seem, at first, a trifle obscure. When one realises, however, that this new maritime organization will deal with matters concerning safety of life at sea, the I.M.O.'s presence at the meeting will become clear. Readers of this magazine may not be familiar with the close association that international meteorology has had with shipping and the following points are of interest.

It was in 1853 that the first International Meteorological Conference was held in Brussels and the prime mover in this Conference was an American naval officer, Matthew Fontaine Maury. The chief purpose of this Conference was to consider international co-operation amongst merchant shipping in order to obtain information about the meteorology and currents of the oceans. Shortly after that date the British Meteorological Office was formed under Admiral Fitzroy and at that time, too, the prime purpose of the Meteorological Office was to safeguard shipping.

Since the days of Maury and Fitzroy the scope of meteorology has extended into many other spheres, notably that of aviation, but meteorology has still a very important part to play in its relation to shipping. Gales still produce high seas; fogs set in with disturbing regularity; in certain regions of the world ice is still a great menace to shipping; and the navigator continues to seek information which will prevent his vessel being set off her course by unsuspected currents.

Despite mechanical propulsion, larger vessels and all the scientific aids now available to the seaman, the navigator must still be as vigilant as ever he was in the days of the sailing ship, in fact, even more so, as he has higher speeds to contend with, and even the largest ship can be damaged by a heavy sea. The provision of accurate and regular meteorological information for shipping is a permanent necessity—not only for safety of life and property at sea—but also for commercial reasons.

The I.M.O. has realised this fact, as well as the very practical consideration that co-operation by ships is essential if a reasonable network of observations from the greater part of the globe's surface—the oceans—is to be attained. Assisted by the technical advice of the Maritime Commission, the I.M.O. has continued to display a very active interest in shipping matters and has taken part at the various conferences which have been held on the subject of safety of life at sea.

The I.M.O. representative, in his address to the Conferenee, stressed these facts, and emphasised the I.M.O.'s desire, as a servant of the world, to provide the best possible meteorological service for the shipping of all nations in all oceans.

Both the above-mentioned Conferences on Safety of Life at Sea have been held in London, the first one being in 1914 as a result of the *Titanic* disaster, and another in 1929.

At this last-named Conference the present International Convention for Safety of Life at Sea evolved and another Conference was held in London, in May and June this year, to revise this Convention (see report on p. 198). This Conference was linked up with the functions of the newly formed Intergovernmental Maritime Consultative Organization.

In 1912, the International Meteorological Organization was instrumental in arranging an International Conference on the subject of storm warnings; this was also held in London.

With the object of ensuring adequate co-ordination in matters concerning safety of life at sea, in preparation for the Conference in London, a Preparatory Committee of Experts was formed and met in London in February of this year. At this Conference, the International Civil Aviation Organization, the International Telecommunication Union, the International Meteorological Organization, and the Provisional Maritime Consultative Council took part, and a scheme was drawn up whereby each organization agreed to consult the others as necessary concerning matters within their scope affecting safety at sea.

The Convention of the Intergovernmental Consultative Organization needs to be ratified by Governments before it can officially take any action. When one considers the importance of shipping to world prosperity, the potential value of the new organization will be obvious, and it is hoped that its birth will not only contribute to greater safety of life at sea but to a greater understanding among the shipping nations of the world.

INTERNATIONAL CONFERENCE ON SAFETY OF LIFE AT SEA, LONDON, 1948

BY COMMANDER C. E. N. FRANKCOM, R.N.R.

The third International Conference on Safety of Life at Sea was held in London under the chairmanship of Sir John Anderson, from April 23 to June 10, 1948. The Conference took place at the Institute of Civil Engineers and was attended by thirty nations. Admiral Farley (Chief of the U.S. Coastguard Service) was elected Vice-Chairman.

The writer attended the Conference as an official observer for the International Meteorological Organization. The meteorological interest in this subject is quite considerable and it will be evident to readers of this article that safety at sea is necessarily closely related to weather conditions. In the days of the sailing ship it is true that weather played an even greater part in the life of the seaman, for the winds provided the motive power. Even today, however, as will be seen from the study of any reports of shipping casualties weather still plays an important part in the shipping industry. Even the largest ship can get damaged if she tries to steam at full speed into a heavy sea. Comparatively minor damage done to the steering apparatus of a ship may make her helpless in heavy weather and thereby make her a casualty. Despite modern, scientific aids to navigation, many ships collide or run ashore in thick weather and ships get beset in ice every year in the Baltic. A vessel which has deficient stability may, in heavy weather, shift her cargo, take a dangerous list and eventually capsize. Temperate-zone gales and tropical storms exact their annual toll of ships and of seamen's lives—rather particularly in the case of the smaller coasting type of vessel—despite the provision of modern life-saving appliances and the heroic work of the lifeboats and other safety services (including aircraft searches).

The first International Conference on Safety of Life at Sea was convened as a result of the *Titanic* disaster and took place in London in 1914. The results of this first Conference never bore fruit because the 1914–18 war intervened, and the Convention was never ratified. In 1929, however, another Conference was held and the International Convention for Safety of Life at Sea was instituted.

The 1948 Safety Conference dealt with many matters concerning safety at sea, such as standards of construction of ships, strength of materials, stability, life-saving appliances aboard ships, rule of the road at sea, and radio, including electronic aids to navigation. The general atmosphere of the Conference was one of cordiality and of an earnest desire by all concerned to ensure that those who go down to the sea in ships should not be lacking in adequate provisions to ensure that their voyages should be conducted with safety. Lessons learnt during the recent war, coupled with the advance of scientific knowledge in the interval since the 1929 Convention, have done much to raise safety standards, and the provisions of the new Convention contain many notable advances.

Much of the subject matter dealt with precautions to ensure safety after a casualty had occurred. The meteorological provisions of the Convention are, however, largely designed in an endeavour to give warning of approaching danger, so that the mariner can take seamanlike precautions to avoid it.

Article 34 of the 1929 Convention placed upon masters of ships an obligation of informing other shipping and meteorological services of the presence, or suspected presence, of tropical storms, and Article 35 provided for the collection from ships of radio-weather messages and the issue to ships of weather forecasts and other meteorological information, as necessary.

At the Conference this year, the meteorological provisions of the Convention were further strengthened and the texts of the latest Articles on this subject read as follows:—

REGULATION 3.—Information Required in Danger Messages

The following information is desired in danger messages, the time in all cases being Greenwich Mean Time:

(*a*) Ice, derelicts and other direct dangers to navigation.

- (i) the kind of ice, derelict or danger observed;
- (ii) the last position of the ice, derelict or danger when last observed;
- (iii) the time and date when the observation was made.

(*b*) Tropical storms—(hurricanes in the West Indies, typhoons in the China Sea, cyclones in Indian waters, and storms of a similar nature in other regions).

(i) A statement that a tropical storm has been encountered. This obligation should be interpreted in a broad spirit, and information transmitted whenever the master has good reason to believe that a tropical storm exists in his neighbourhood.

(ii) Meteorological information. Each shipmaster should add to his warning message as much of the following meteorological information as he finds practicable:—

Greenwich Mean Time, date and position of the ship when the observations were taken;
barometric pressure (stating millibars, inches, or millimetres, and whether corrected or uncorrected);
barometric tendency (the change in barometric pressure during the past 3 hours);
true wind direction;
wind force (Beaufort scale);
state of the sea (smooth, moderate, rough, high);
swell (slight, moderate, heavy) and the true direction from which it comes—period or length of swell (short, average, long) would also be of value;
true course and speed of ship.

(*c*) Subsequent observations. When a master has reported a tropical or other dangerous storm, it is desirable, but not obligatory, that other observations be made and transmitted hourly, if practicable, but in any case at intervals of not more than three hours, so long as the ship remains under the influence of the storm.

Examples

Ice

TTT Ice. Large berg sighted in 4605 N., 4410 W., at 0800 G.M.T. May 15.

Derelict

TTT Derelict. Observed derelict almost submerged in 4006 N., 1243 W., at 1630 G.M.T. April 21.

Danger to Navigation

TTT Navigation. Alpha lightship not on station. 1800 G.M.T. January 3.

Tropical Storm

TTT Storm. 0030 G.M.T. August 18. 2204 N., 11354 E. Barometer corrected 994 millibars, tendency down 6 millibars. Wind NW., force 9, heavy squalls. Heavy easterly swell. Course 067, 5 knots.

TTT Storm. Appearances indicate approach of hurricane. 1300 G.M.T. September 14. 2200 N., 7236 W. Barometer corrected 29·64 inches, tendency down ·015 inches. Wind NE., force 8, frequent rain squalls. Course 035, 9 knots.

TTT Storm. Conditions indicate intense cyclone has formed. 0200 G.M.T. May 4. 1620 N., 9203 E. Barometer uncorrected 753·3 millimetres, tendency down 5 millimetres. Wind S by W., force 5. Course 300, 8 knots.

TTT Storm. Typhoon to south-east. 0300 G.M.T. June 12. 1812 N., 12605 E. Barometer falling rapidly. Wind increasing from N.

REGULATION 4.—Meteorological Services

(*a*) The contracting Governments undertake to encourage the collection of meteorological data by ships at sea and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation. Administrations shall encourage the use of instruments of a high degree of accuracy, and shall facilitate the checking of such instruments upon request.

(*b*) In particular, the contracting Governments undertake to co-operate in carrying out, as far as practicable, the following meteorological arrangements:—

(i) To warn ships of gales, storms and tropical storms, both by the issue of radio messages and by the display or appropriate signals at coastal points.

(ii) To issue daily, by radio, weather bulletins suitable for shipping, containing data of existing weather and ice conditions, forecasts, and when practicable, sufficient additional information to enable simple weather charts to be prepared at sea.

(iii) To prepare and issue such publications as may be necessary for the efficient conduct of meteorological work at sea.

(iv) To arrange for selected ships to be equipped with tested instruments (such as a barometer, a barograph, a psychrometer and suitable apparatus for measuring sea temperature) for use in this service, and to take meteorological observations at standard synoptic hours (at least four times daily, whenever circumstances permit) and to encourage other ships to take observations in a modified form, particularly when in areas where shipping is sparse; these ships to transmit their observations by radio for the benefit of the various official meteorological services, repeating the information for the benefit of ships in the vicinity. When in the vicinity of a tropical storm or of a suspected tropical storm, ships should be encouraged to take and transmit their observations at more frequent intervals whenever practicable, bearing in mind navigational preoccupations of ships' officers during storm conditions.

(v) To arrange for the reception and transmission by coast radio stations of weather messages from and to ships. Ships which are unable to communicate direct with shore should be encouraged to relay their weather messages through ocean weather ships or through other ships which are in contact with shore.

(vi) To encourage all masters to inform ships in the vicinity and also shore stations whenever they experience a wind speed of 50 knots or more (force 10 on the Beaufort scale).

(vii) To endeavour to obtain a uniform procedure in regard to the international meteorological services already specified, and, as far as is practicable, to conform to the recommendations made by the International Meteorological Organization, to which the contracting Governments may refer for study and advice any meteorological question which may arise in carrying out the present Convention.

(*c*) The information provided for in this Regulation shall be furnished in form for transmission and transmitted in the order of priority prescribed by the Radio Regulations, and during transmission " to all stations " of meteorological information, forecasts and warnings, all ship stations must conform to the provisions of the Radio Regulations.

(*d*) Forecasts, warnings, synoptic and other meteorological reports intended for ships shall be issued and disseminated by the national service in the best position to serve various zones and areas, in accordance with mutual arrangements made by the contracting Governments concerned.

The meteorological interest in the Conference also extended to the question of radio-telegraphy and radio-telephony, owing to the important part that communications play in this subject generally. A resolution was passed urging governments to ensure that the transmission of radio weather messages should be free of cost to shipping.

The continuance of the International Ice Patrol in the Grand Bank of Newfoundland district, which is entrusted to the U.S. Coastguard was a further item of considerable interest to meteorologists.

The general result of the Conference was extremely satisfactory and the new convention should do much to prevent loss of life and property at sea in the future.

ANOMALIES OF BAROMETRIC PRESSURE AT COASTAL STATIONS

BY A. W. LEE, D.SC.

Discrepancies have frequently been noted between the mean-sea-level pressures obtained from the barometric readings at certain coastal stations and the corresponding values indicated from the synoptic charts. The observed pressures for these stations appear to be too low, especially during strong winds. In some cases, such as Dungeness or Portland Bill where the barometers are set up in lighthouses, it has been suggested* that the action of wind upon such a building produces a suction or " chimney " effect and that in consequence the mean pressure inside is lower than that outside. The discrepancy has also been noted, however, in the readings for other coastal stations at which the pressures are obtained from barometers housed in more ordinary structures; accordingly a more general explanation was required and A. F. Crossley† has suggested that the anomalies may indicate the variations of pressure accompanying distortion of the air flow on sites which are over-exposed to the wind. Crossley showed that a reasonable increase of wind speed would be associated with a pressure change of the right order of magnitude but, in replying to the discussion on the paper, remarked that there were no observations then available for comparison.

This question came forward again in 1943 when the Meteorological Office issued instructions for the inspection of St. Abb's Head, emphasising that the station had frequently shown anomalies, the barometer appearing too low. It was therefore decided to try to carry out systematic determinations of the barometer which, although of necessity in a well exposed building at a height of 280 ft. above sea level, would not be described as in an abnormal situation; the results obtained are set out in the following paragraphs.

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*London, Meteorological Office, Gazetteer of British meteorological stations used in the preparation of synoptic reports. London, 1931.

†CROSSLEY, A. F.; Note on the variation of pressure accompanying a distortion of air flow. *Quart. J. R. met. Soc., London*, **64**, 1938, p. 477.

For any station the barometric error (" observed " minus " true " pressure) at any time is taken as the difference between the observed value and that estimated from the isobaric distribution of the corresponding synoptic chart. The general trend of the isobars on the chart should not be influenced by the observation under comparison, or by reports from adjacent stations which are liable to be influenced by similar errors. Thus it was frequently necessary to smooth and redraw the isobars around the station before estimating the " true " pressure. Individual values of the errors obtained in this way are liable to uncertainties up to about 0.5 mb., but these are not systematic and would be eliminated with a sufficiently large number of determinations.

The " observed " and " true " pressures at St. Abb's Head have been compared at each of the hours 0100, 0700, 1300 and 1800, during the months January to July 1943. It was found that on 356 of the 848 occasions the difference between the " observed " and " true " pressures was less than 0·5 mb.; deviations exceeding this limit occurred on the following numbers of occasions:—

	mb.	Low	High
Exceeding	±0·5	470	22
Exceeding	±1·0	274	9
Exceeding	±2·0	63	1
Exceeding	±3·0	13	0

There is a striking preponderance of barometric readings which are too low, the median of the error, computed from the 848 observations, amounting to −0·7 mb.

The deficit in the observed pressures was examined for diurnal and seasonal variations by summarising the data for the various hours and for winter and summer months respectively. The diurnal variation is small; the median error of the 212 values amounts to −0·7 mb. at 0100, to −0·8 mb. at 0700, to −0·6 mb. at 1300 and again to −0·6 mb. at 1800, and a more extensive series of comparisons would be needed before it can be accepted as of physical significance. The median error of the seasonal variation amounts to −0·8 mb. in the months January to March and to −0·5 mb. from May to July; thus the values for the two sequences of months support the hypothesis that the differences are associated with the airflow, the median values of wind force and of barometric discrepancy both being greater in winter.

A close relation between barometric discrepancy and wind is brought out from the following tabulation giving the medians of the errors associated with specified ranges of speed:—

Beaufort force	0	1	2	3	4	5	6	≥7
Median error	−0·4	−0·4	−0·3	−0·5	−0·9	−1·5	−1·7	−1·9
Number of values	32	88	112	214	216	123	43	20

The uniformity of the errors for calms and for winds up to Beaufort force 3 suggests that the results may all be subject to a systematic error of −0·4 mb.; this is equivalent to an error of about 10 ft. in the height of the barometer above sea level. With stronger winds, the barometric error attributed to exposure is apparently superposed and increases progressively with the speed.

Fig. 1 shows the anomalies of pressure at St. Abb's Head from January to July 1943 classified according to wind speed and direction; medians of the error are given for all cases except those with less than four observations. The increase of barometric anomaly with wind speed is shown in all directions from which data are available, but unfortunately moderate or strong winds were infrequent or lacking from some directions during the period covered by the observations.* The station is surrounded by sea from west-north-west through north and east to south-south-east, and it is notable that for each range of forces the barometric anomalies are generally larger with winds from landwards than with those from seawards.

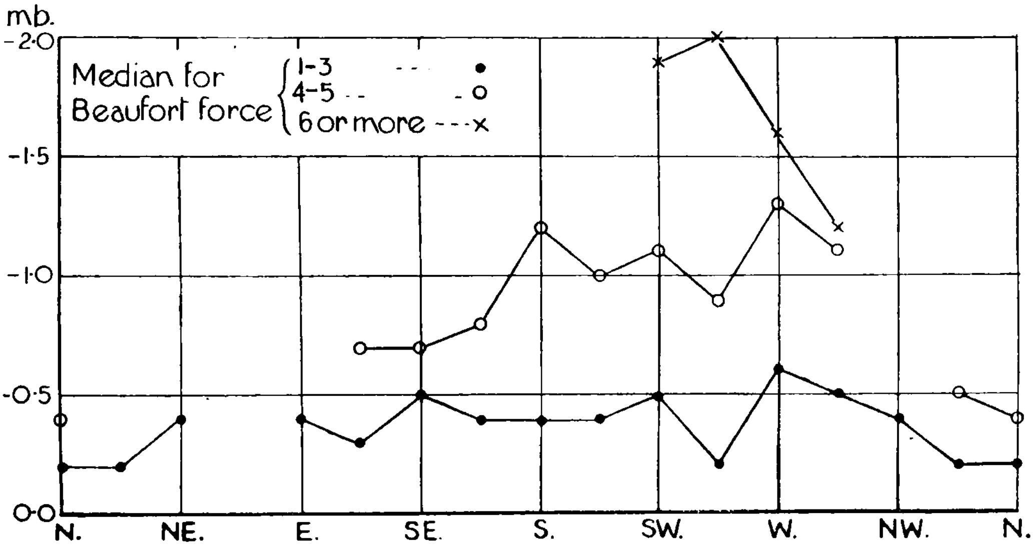

FIG. 1—ANOMALIES OF PRESSURE AT ST. ABB'S HEAD, JANUARY–JULY 1943

Classified according to wind speed and direction

Thus, since anomalies of 2 mb. or more are associated with landward winds, there seems to be no reason to believe that such anomalies occur only at coastal stations. Anomalies might also be expected to occur at well exposed inland stations, especially those at considerable heights above sea level in irregular hilly country. Also, it seems reasonable to suspect that many other barometers may also be anomalous; even if the discrepancy generally amounted to several tenths of a millibar, it would be by no means negligible in view of the consistency claimed for barometric measurements.

METEOROLOGICAL RESEARCH COMMITTEE

The third meeting of the Physical Sub-Committee was held on July 15. One of the papers considered dealt with the evidence from upper air temperature measurements by aircraft for diurnal variation of temperature in the upper air. It was concluded that these measurements do not provide evidence of such variation.

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*An earlier unpublished comparison by B. C. V. Oddie of the barometric pressures at St. Anne's Head in south-west Wales with those at Pembroke Dock 10 miles away showed discrepancies of approximately the same magnitudes as at St. Abb's Head.

Another paper *M.R.P.* No. 402 by Dr. R. Frith, described a series of flights by Meteorological Research Flight aircraft during which the aircraft flew along a grid-pattern path covering an area approximately 30 to 50 miles square. Very frequent measurements of temperature and humidity were made. When these measurements were subsequently plotted it was found that isopleths of temperature and humidity could be drawn showing a coherent pattern in which isopleths of high temperature were very approximately coincident with isopleths of low humidity. Investigation of these grid patterns is to continue.

ROYAL METEOROLOGICAL SOCIETY

The 1948 summer meeting of the Royal Meteorological Society was held at the Rothamsted Experimental Station, Harpenden, on July 14.

Most of the Fellows and their guests travelled from London by coach, reaching Rothamsted soon after 11.30 a.m. On arrival the party was split into three groups, each of about twenty, and during the day everybody visited the Farm, the Plant Pathology Department, the Physics Department and the Meteorological Enclosure.

Miss Skidmore conducted the party round part of the farm and gave a general description of the experiments which have been continuously carried out since the middle of the last century. In Broadbalk Field, wheat has been grown every year since 1843, and in 1852 an experiment was started to find the effect of different manurial treatments on 17 long parallel strips, each about half an acre in area. Not until 1925 was any change made in the experiment when it became necessary to fallow one-fifth of the field each year because it had become badly infested with weeds, particularly poppies and black bent. The difference in the yields of the various strips was evident even to untrained eyes, and it was not surprising to hear that the strip with 14 tons of farm manure to the acre bore about 3 times as much as the strip with no manure whatever and 2½ times as much as the strip which received no nitrogen. On the other hand, the strip with 6 cwt. of sulphate of ammonia, 3½ cwt. of superphosphate, 2 cwt. of sulphate of potash and 1 cwt. of sulphate of magnesia per acre has roughly the same yield as the strip with farm manure.

The analysis of the water from the tiled drains which were laid down under each strip has provided important data on the losses of the constituents of the various manures. For all practical purposes, phosphate and potash are completely retained in the soil, but nitrate and calcium carbonate come through into the drains and are lost to the plants. Gardeners in the party no doubt made a note to apply their sulphate of ammonia in the spring and not in the autumn.

A different experiment was begun in 1882 on an acre strip of the standing crop in the west of Broadbalk Field. This crop was left standing and allowed to compete with the weeds; four years later a few stunted plants were found and were barely recognizable as cultivated wheat. Since then the weeds have completely taken possession and transformed the strip into what is known as the Wilderness. Part of this is left completely untouched and now carries a dense growth of bushes and young trees, and the rest is periodically cleared of bushes to allow the ground vegetation to develop.

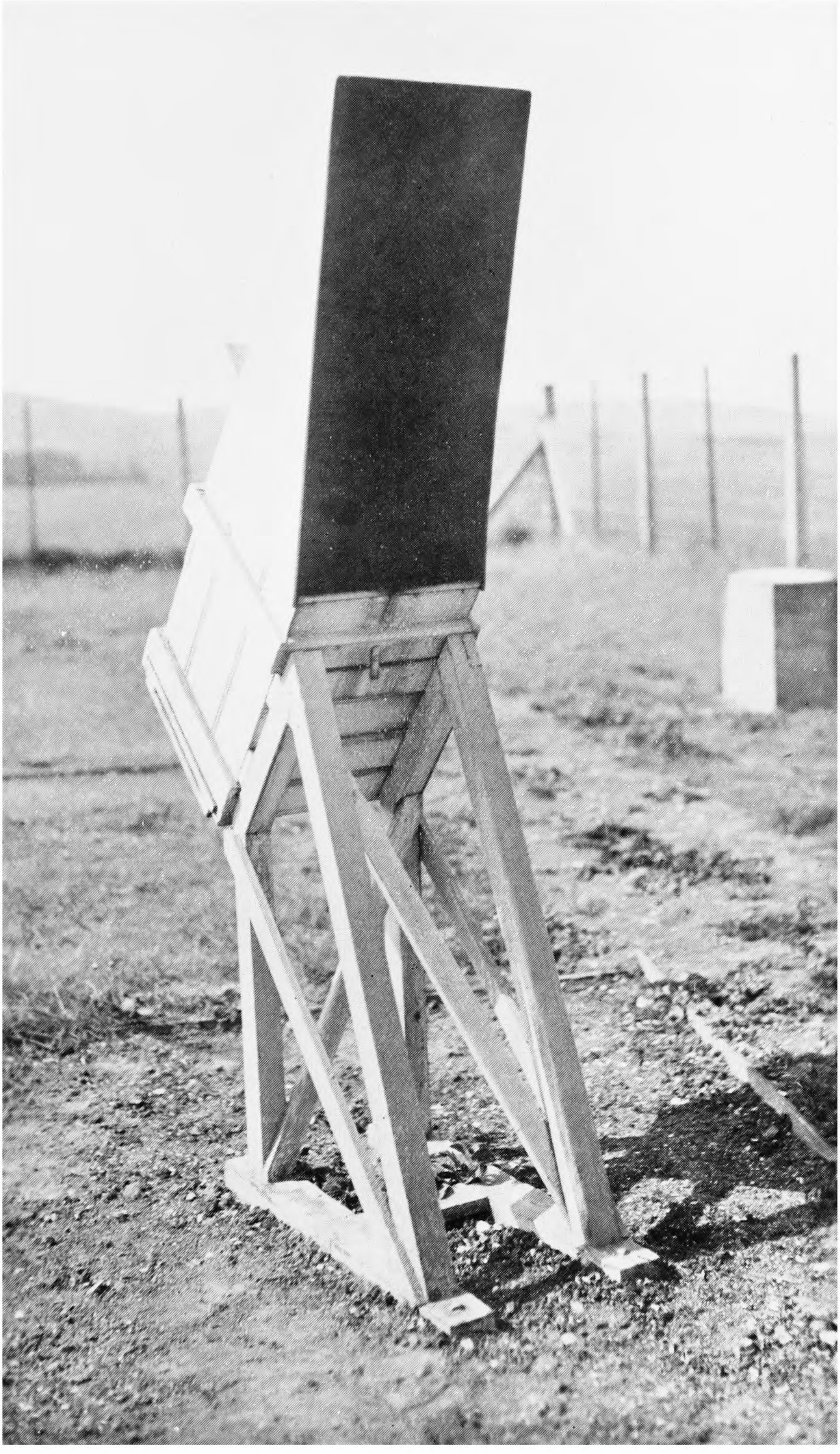


FIG. 1—EXTERNAL HOUSING OF STARSHINE CAMERA
(see p. 193)

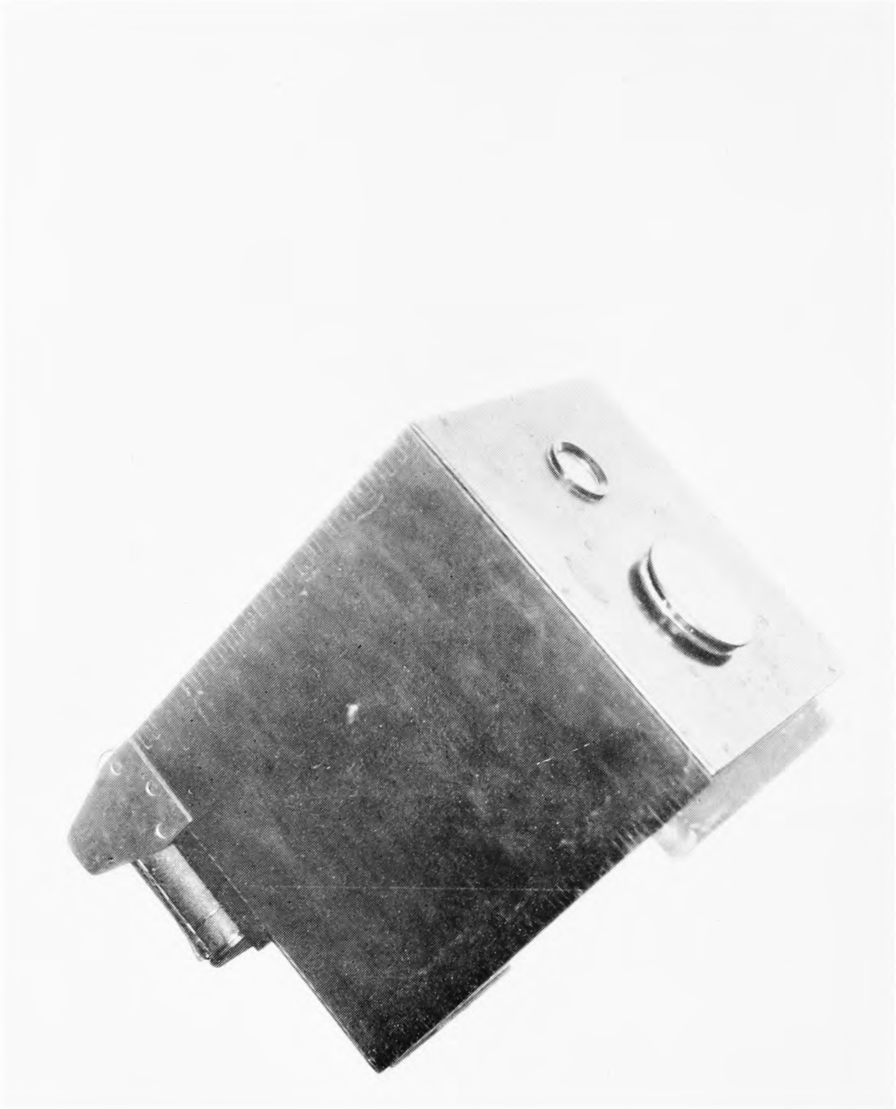


FIG. 2—COMPLETE CAMERA
(see p. 194)

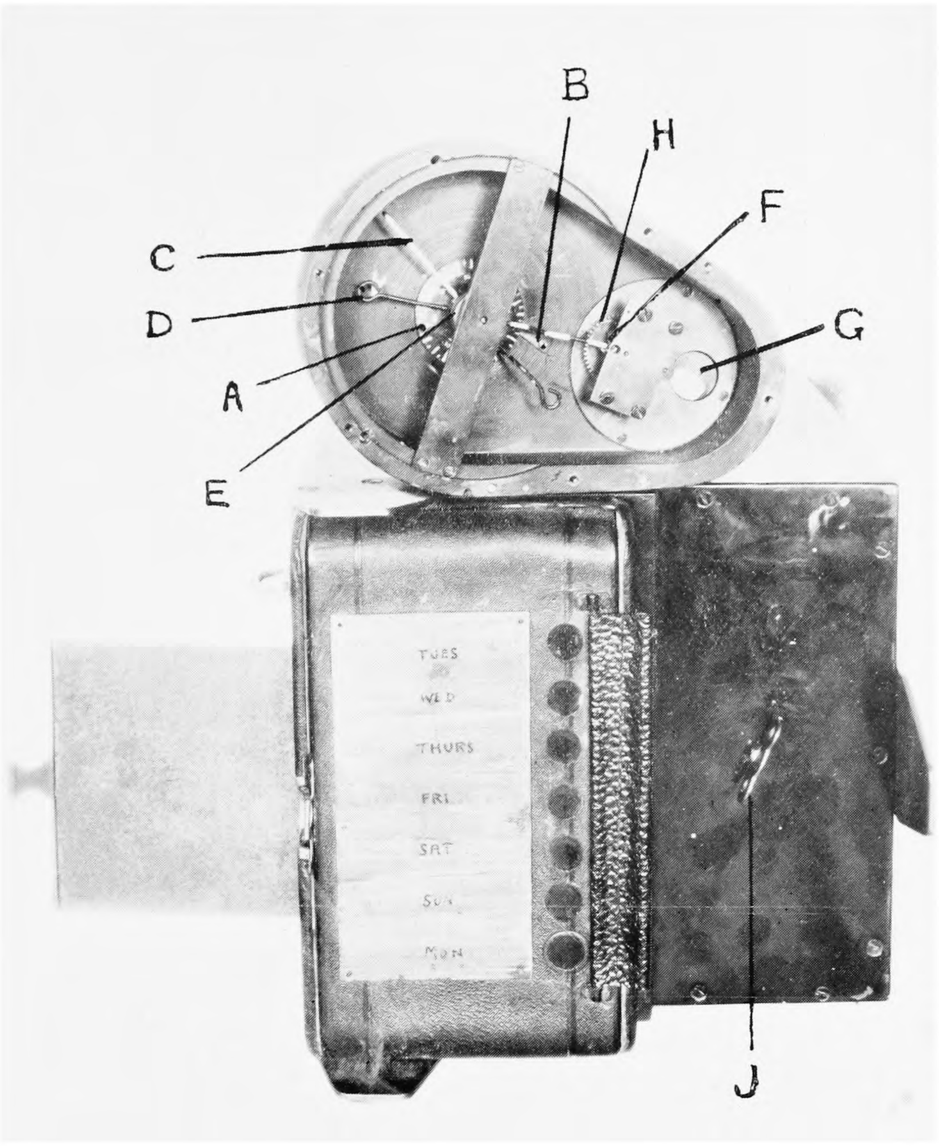

B
H
F
C
D
G
A
E
TUES
WED
THURS
FRI
SAT
SUN
MON
J

FIG. 3—BACK OF THE CAMERA WITH SHUTTER MECHANISM PLACED ON TOP

A	24-hour dial
B	Time index
C, D	Striking arms
E	Milled locking nut
F	8-point star wheel
G	Rotary shutter
H	Gear wheel
J	Clock-winding key

(see p. 194)

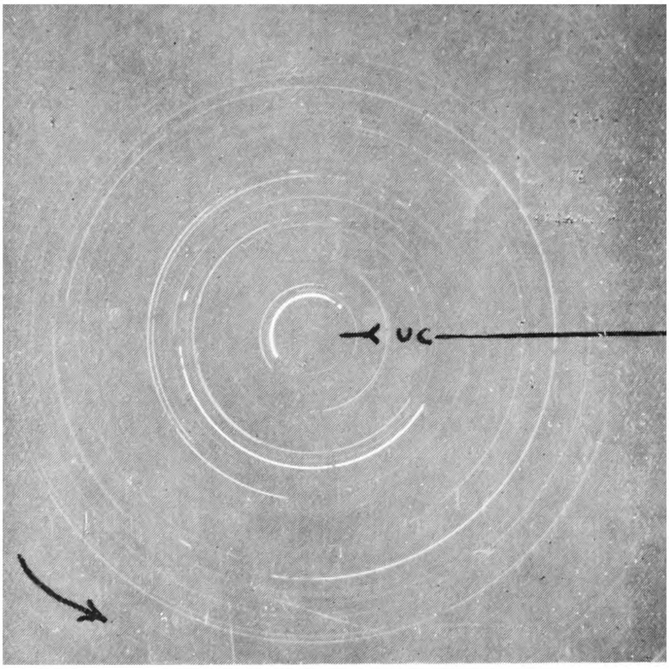


FIG. 4—TYPICAL NIGHT-SKY RECORD
Porton, February 19–20, 1936 ; moon's age : 26 days
U.C. = Upper culmination

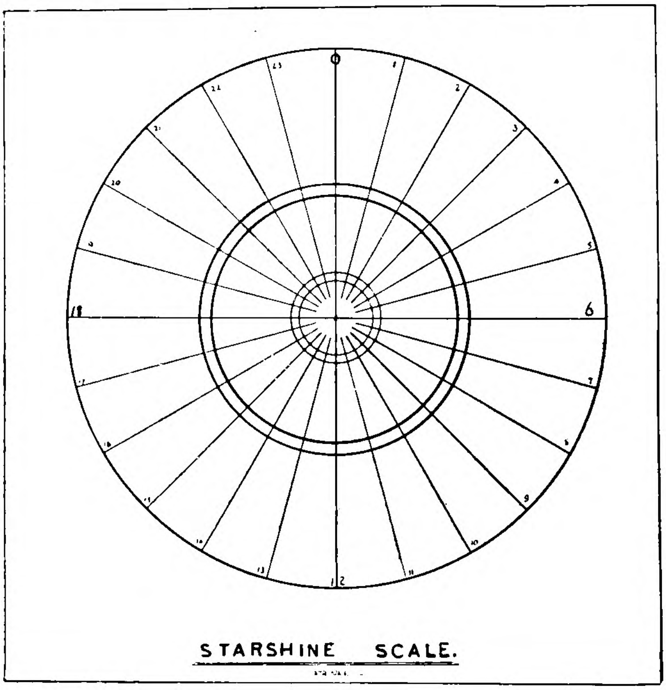

0
1
2
3
6
9
12
18
STARSHINE SCALE.

FIG. 5—GLASS SCALE FOR MEASURING STAR TRACES
(see p. 194)

After leaving Broadbalk, a short visit was made to Hoosfield, Little Hoos and Long Hoos. In Hoosfield, experiments on continuous barley began in 1856, using a cross-dressing system. The mineral manures are laid along strips which are crossed at right angles by another set of strips carrying various nitrogenous manures. The effects on the barley crops are very similar to those obtained on wheat on Broadbalk.

On Long Hoos a six-course rotation experiment was started in 1944 and will last for 60 years. It is designed to test the effect of deep (12 in.) ploughing against shallow (6 in.) and of dung and certain fertilizer treatments. This experiment differs from those mentioned above in that the experimental area is divided into small plots, each of which will finally have carried all the series, sugar beet, barley, seeds, wheat, potatoes, oats with various ploughing and manurial treatments.

Dr. Penman gave the party an outline of the work of the Physics Department. The research which is now being carried out includes the study of the properties of clays, and meteorological experiments mainly concerned with microclimatology.

Potato blight is caused by a virus which is carried by the peach aphis and, in order to study the effect of weather on these aphids, the plant pathologists have asked for the microclimate of potato fields to be investigated. The Physics department has therefore devised an instrument using thermistors to measure dry- and wet-bulb temperatures and wind speeds at various heights, and an attempt is also being made to record radiation on similar principles.

The Meteorological Enclosure in Great Field contains the equipment to give standard climatological observations and also many others for which Rothamsted has long been noted; these include drainage through bare soil 20, 40 and 60 in. deep, evaporation from open water surfaces and from bare soil, and transpiration from turf. Continuous records of dew point are also made, the method of recording depending on the fact that the dew point is roughly as far below the wet-bulb temperature as the wet-bulb is below the dry-bulb temperature. Wind, temperature and humidity are also recorded from various heights on the 105-ft. tower which was installed to study the drift of insects in the air.

In the Plant Pathology Department Dr. Gregory briefly described the work now in progress on the virus diseases of both the persistent and non-persistent types. Once again the importance of microclimates became evident as a factor in the transmission of both virus and epidemic fungus diseases.

There was time for no more than a short visit to the electron microscope, the principles of which were explained by Mr. Nixon. By way of demonstration we saw a zinc-oxide smoke magnified some 10,000 times.

After tea the President expressed the Society's thanks to all the Rothamsted staff who had helped to make the meeting so enjoyable. In his reply the Director, Dr. Ogg, said that he and his staff would welcome any of the Fellows who would care to return to study particular aspects of the work in greater detail.

LETTERS TO THE EDITOR

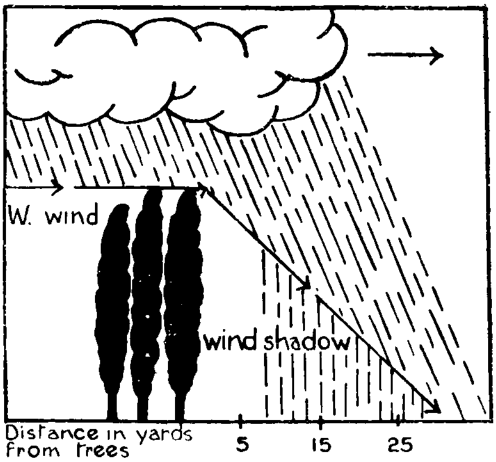
Rain shadow

On the western edge of a large rectangular garden in the country near Hanover, there is a row of poplar trees 35–40 yards high and 20 yards broad. Even in the wet summer of 1946 the western part of the garden showed signs of aridity but in 1947, over the western third, vegetation, including the relatively deeply rooted gooseberry and raspberry bushes, withered away. As the garden is in the middle of a hollow with good subsoil-water conditions these effects of dryness could only be attributed to the rain-shadow effect of the poplars.

Readings with rain-gauges over the period May 1 to August 31, 1947, at varying distances from the row of trees gave the following results :—

Distance east of the poplars (yd.) ..	0–5	5–15	15–25	35
Measured rainfall (mm.)	8–33	33–76	76–110	110
Long-period average (mm.) ..	—	—	—	175

The effect of the trees was enhanced, in the summer of 1948, by the rainfall occurring in the form of showers accompanied by westerly squalls.



Visual observations during showers showed that the portion up to five yards from the trees received only drizzle forced through them with some drippings from the leaves after the shower. The next section, from 5 to 15 yards, received the heaviest drops and the section, from 15 to 25 yards, received a larger quantity and in winds of force 3 to 5 the full intensity of the shower. Only beyond 25 yards was the shower always received at full strength. The general picture is shown in the diagram.

W. LAMMERT

(20*b*) *Einbeck/Hanover, Bismarkstr.* 21

[Mr. Hogg points out that Hudleston (*British Rainfall* 1928) found that a gauge the same distance from a wood as the height of the trees caught only 70 per cent. of the rainfall measured under a standard exposure nearby during a period of westerly winds in winter. Herr Lammert's measurements are thus large compared with Hudleston's particularly as the former were made in summer and the latter in winter but possibly the difference in the breadths of the belts of trees accounts for the difference between them.—Ed. *M.M.*]

Evaporation shadow

The following phenomenon in connexion with the effect of sunshine upon evaporation may be of interest.

The afternoon of June 3, 1948, was showery with squally westerly winds and intermittent sunshine. At about 1435 G.M.T. I noticed that although the tar macadam path leading to the office was perfectly dry, there was marked on this path a perfect shadow of a gate as " wet earth ". There had previously been a sharp shower which terminated at about 1405 and this was followed by a period of brilliant sunshine. When I observed the phenomenon the sun was obscured by cloud. I remained at the gate for a few moments so that I could watch the sun cast the shadow of the gate on the path. This shadow was almost coincident with the wet one.

J. E. BELASCO

June 4, 1948

Thunderstorm observations

Following Mr. Golde's note in the March issue of the *Meteorological Magazine*, it may be useful to record that many of the details asked for in the proposed census of thunderstorms have already been collected by the Thunderstorm Census Organization since 1924, and by Mr. C. J. P. Cave prior to that date, working in conjunction with the Meteorological Office.

A network of about 3,000 observing stations has been built up in the British Isles, with the aid of the observers of the British Rainfall Organization, radio appeals and the help of the Country Press. Some of the results have been published in the *Quarterly Journal of the Royal Meteorological Society*, but the majority have appeared in *British Thunderstorms*. Other data are available through the inquiry service of the Thunderstorm Census Organization at its Headquarters at Langley Terrace, Oakes, Huddersfield.

Daily charts of storm areas have been prepared for a number of years and a series of monthly and quarterly distribution maps have been published. Storm tracks have been worked out in numerous cases, and maps, showing the movement and interaction of storm fronts by means of hourly isochrones, have been published for certain dates.

The " isokeraunic level " method has not been used, in that it has been possible to replace the somewhat loose definition of " thunder heard " by the much more definite indication of " thunder overhead " or within a mile either vertically or horizontally. It is clear that if two storms on different days run on almost parallel tracks, separated by, say ten miles, the " thunder heard " method is likely to give a reading of two for the intervening country between the tracks, while the " overhead storm " method will give the correct result of zero. The suggestion of separate storms on almost parallel tracks is not merely a technical situation chosen to illustrate a method, but an arrangement which very frequently happens on account of the nature of thunderstorms and the manner in which they develop and move.

The analysis of data involves considerable triangulation between groups of stations and between stations within a group; in this way it becomes possible to maintain a reasonable 24-hour watch without the responsibility of excessive hours of observation resting on particular observers.

Data regarding the number of lightning flashes to earth have been collected from time to time, but it has not been found easy to analyse these records with any degree of definiteness. The personal factors of the observers and the influence of their surroundings are matters which are difficult to assess. It has been found much more valuable to ask for reports of actual damage—which a great number of people may be expected to record with both great accuracy and sustained interest—and to plot these indications on the thunderstorm maps. In this way " areas of damage " can be arrived at and classified. Thunder or lightning occurs somewhere in the British Isles on about one day in two, and " areas of damage " occur quite frequently. Thousands of records of damage have been collected and indexed, including some six or seven hundred of damage to trees alone.

If any evidence outside the existing questionnaires of the Thunderstorm Census Organization is required, it would be easy to extend or modify the present arrangements and observing network. Damage map folders on the scale of two miles to the inch were issued about 1935 in order that Observers could plot their local damage.

S. MORRIS BOWER

Thunderstorm Census Organization

Langley Terrace, Oakes, Huddersfield, June 25, 1948

In the March issue of this journal a short article was published under the above heading. The purpose of this article was to enlist voluntary observers with a view to submitting data on the occurrence of thunderstorms with particular reference to the frequency of lightning strokes to earth.

I was, of course, aware of the excellent work done in the meteorological field by the Thunderstorm Census Organization under the direction of Mr. Morris Bower. The Thunderstorm Census Organization, which has been in operation since 1924, has built up a large body of observers and has published several publications giving detailed information on annual thunderstorm activities up to the year 1937.

It is understood that the information received by this organization is examined and tabulated in three ways :—

(1) number of days with thunder heard,
(2) areas of overhead storms, and
(3) areas in which damage has been reported.

While the value of the information collected by the Thunderstorm Census Organization is of undoubted value to the meteorologist it will be recognised that the new survey initiated in the March issue of this journal seeks to obtain more highly specific information. As explained before, thunderstorms which produce no lightning strokes to earth do not affect the continuity of electricity supply and are therefore of no direct interest in the present investigation. Of the three above items the one mentioned last may come nearest the information required for the new census. However, it must be realised that, in the majority of cases, no noticeable damage results from a lightning flash to earth, and that even if damage is done it may often be so slight as to escape notice.

The observation of thunderstorms with respect to the frequency of discharges to earth and the general severity of the storm require the full attention of any observer. It is for this reason that the new survey has been started. A number

THUNDERSTORM OBSERVATIONS

Approximate Time and Duration of Storm ……………………………………………………

……………………………………………………………………

Direction of Movement of Storm ……………………………………………………

……………………………………………………………………

……………………………………………………………………

Severity of Storm ……………………………………………………

……………………………………………………………………

……………………………………………………………………

Estimate of Number of Lightning Flashes to Earth ……………………………………………………

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

Date ………………………………… **Signed** …………………………………

of offers of assistance have already been received and helpers have been supplied with postcards on which their observations are to be submitted. The form of this postcard can be seen from the illustration above. Additional observers will be most welcome and they are requested to write to The British Electrical and Allied Industries Research Association, 5 Wadsworth Road, Perivale, Middlesex.

R. H. GOLDE

British Electrical and Allied Industries Research Association,
5 *Wadsworth Road, Perivale, Middlesex, July* 13, 1948

NOTES AND NEWS

Turbulence in clear air near a warm-front surface

In general, marked turbulence is not expected in a warm front in temperate regions except in those rather exceptional circumstances when considerable instability exists in the warm air mass, and in the latter case considerable cloud development would also be expected. The following is an account of rather different circumstances met by a British meteorological reconnaissance aircraft over the North Atlantic in January 1948. The meteorological observations were made by F/Sgt. A. S. Goodin and the aircraft was an R.A.F. Halifax specially equipped for meteorological reconnaissance.

At 1400 G.M.T. on January 15, 1948, the aircraft carried out a climb from near the sea surface to 500 mb. (18,000 ft. approximately) in 54°50′N. 21°50′W. At this position a layer of cold air flowing from NW. was being replaced at high levels by warm air. The associated warm front was placed on the surface charts as 300 miles to the south-west. This front lay north-west to south-east and was advancing north-east at about 10 kt. In the immediate vicinity of the ascent the clouds consisted of 5 tenths cumulus, base 940 mb.

top 830 mb.; 3 tenths cumulus, base 950 mb. top 690 mb.; and 4 tenths cirro-stratus, base above 500 mb. The top of the cold air was reached at 600 mb. (−13°F.) from which level there was an inversion to 540 mb. (−11°F.) followed by an isothermal to the top of the ascent (500 mb.). From the top of the ascent the warm-front cloud could be clearly seen to the south-west. At the bottom of the ascent there was some intermittent moderate bumpiness but this died out during the ascent, the air at 500 mb. being quite smooth. No special observation regarding bumpiness was made during the climb.

After the ascent the aircraft flew north-east (i.e. away from the front) and in the first 50 miles the temperature fell 10°F. Immediately after the fall in temperature severe turbulence was encountered but all this time the aircraft was in clear air. After the first 50 miles the tops of the cumulus (and cumulonimbus) reached 500 mb. and normal intermittent bumpiness occurred.

These observations are of interest in that the exact location of the turbulence with respect to the frontal surface was accurately observed and also in that the aircraft was not in cloud at the time of the severe turbulence. It is not known whether the turbulence was purely due to the lapse rate, possibly associated with clouds rising up at some distance below, or whether the sloping inversion the aircraft flew through had something to do with it.

C. J. M. AANENSEN

Institute of Navigation

On Friday May 21, 1948, in the lecture hall of the Royal Geographical Society, Mr. Francis Chichester read a paper to the Institute of Navigation entitled " Meteorology in aviation: is it obsolete ? " The Chair was taken by Air Chief Marshall Sir John Slessor, K.C.B., D.S.O., M.C.

Mr. Chichester commenced by contrasting the aviation requirements of the nineteen twenties with those of the present day. Then forecasts of wind speed were very necessary because of the low speed of aircraft. Fog was a very great menace and forecasts of visibility for landing were essential, as no instrumental aids were available. Cumulonimbus cloud and icing were not feared so much. Today we have a very different picture. Owing to heavy wing loading, cumulonimbus cloud is greatly feared, but Mr. Chichester stated that the pilot can use his " radar " scanner to locate cumulonimbus and does not require a forecast. He also said that forecasts of icing conditions are unnecessary today, since, if an aircraft commences to collect ice, the pilot has only to turn on his de-icing equipment and get out of the icing area as quickly as possible.

Mr. Chichester went on to discuss whether forecasts of wind speed were needed. In the case of short flights he suggested they were not, since aircraft speeds have increased so much that the wind makes little difference. For landing it was necessary to know the wind speed and direction but these could be obtained from Flying Control. The case for dispensing with wind forecasts on a long flight required more consideration, and, taking a high-level crossing from Shannon to Gander as an example, Mr. Chichester discussed at some length a contour chart of the height of the 500-mb. pressure surface with a " low " between mid Atlantic and Newfoundland. By flying at a constant pressure level of 500 mb. and from his own determinations of wind, the navigator could estimate by the change in wind direction when he was approaching the " low ". He could then make a diversion round the north side of the " low " to take advantage of favourable winds, and complete the crossing to Gander by " single heading " technique. Mr. Chichester suggested that this method might need considerable investigation, but he did not disclose how any estimate of fuel load could be made at all, unless a forecast of wind speed over the Atlantic was obtained before the aircraft left Shannon.

Finally Mr. Chichester came to the question of fog and made the rather astounding statement that the problem of safe landing in fog by instrumental aids would have been solved before now, if it had not been that in the past pilots had relied too much on visibility forecasts in order to avoid landing in fog.

In the discussion that followed the fallacies of at least some of Mr. Chichester's arguments were exposed. Mr. H. H. Lamb appealed for a better understanding between airmen and meteorologists, and suggested that too much dependence should not be placed on instruments, since even these fail at times. Referring to the 500-mb. contour chart discussed by Mr. Chichester, he asked what would have happened to the aircraft if the " low ", instead of being between mid Atlantic and Gander, had been beyond Gander. Mr. R. A. Hamilton said that on at least 25 per cent. of occasions in winter, direct flight between Prestwick and Gander was not possible for the average civil aircraft. How was the pilot to know of these occasions if there were no forecasts ? What happened too, when an aircraft flew into icing conditions so severe that the de-icing equipment could not cope with them ?

Mr. F. Entwistle (Acting Assistant Secretary-General to the Air Navigation Bureau I.C.A.O.) said that Mr. Chichester's knowledge of modern meteorological procedure and practice was not up to date. There was a very great deal in meteorology besides forecasting. The original forecast was only part of the organization involved in an Atlantic crossing. The pilot, navigator and air traffic controller all needed meteorological information. Pressure-pattern flying technique could be used in flight to improve the intended course in respect of duration of flight. Pilots and navigators agree that forecasts for transatlantic flights are generally good.

The Chairman, in some brief closing remarks, stressed the need for full co-operation between airmen and meteorologists, and pointed out that the critical fuel consumption of the newer types of aircraft would lead to increased demands for meteorological information.

It will be apparent from the above account of the paper that Mr. Chichester's diatribe was really directed against the usefulness of aviation forecasts, and it is not thought that even he would propose to dispense with the whole of the present meteorological organization.

OBITUARIES

Sir D'Arcy W. Thompson, F.R.S.—We regret to record the death on June 21 of Sir D'Arcy Thompson, Professor of Natural History in the University of St. Andrews for 64 years.

Meteorology was one of Sir D'Arcy Thompson's many interests particularly in its connexion with oceanography and fisheries. He wrote papers on the surface temperature of the North Sea and North Atlantic published in the Reports of the Fishery Board of Scotland. From 1938 he was the member of the Meteorological Committee nominated by the Royal Society of Edinburgh.

Mr. R. Feige.—We record with regret the death, as the result of wounds received during hostilities in Jerusalem, on May 28, of Mr. R. Feige, well known to many British meteorologists as Government Meteorologist of Palestine.

Mr. Feige commenced meteorological work in Germany where he became Director of the Meteorological Observatory of Breslau. Joining the Meteorological Service of Palestine, following emigration to that country in the late nineteen thirties, he became meteorological officer at Lydda airport. In 1940 he was appointed Government Meteorologist under the Director of Civil Aviation.

Mr. Feige took a prominent part in the revival of international meteorological work since the war and at the time of his death was a member of seven International Meteorological Organization Committees and Commissions and Vice-President of the Commission for Agricultural Meteorology. In the absence of the President of the Agricultural Meteorology Commission he was appointed acting President of that Commission during its meetings at Toronto and led its discussions with marked ability.

Mr. Feige was particularly interested in the applications of meteorology to aviation, medicine and agriculture, and wrote papers on all those subjects. Perhaps his principal work was his " Rainfall Atlas of Palestine " compiled in collaboration with E. Rosenau.

In the last few months before his death he was actively engaged in making arrangements for founding a journal of agricultural meteorology.

He will be remembered not only as a meteorologist of wide interests but also as a genial and entertaining host at his home in Jerusalem.

REVIEW

Plain Words. A guide to the use of English, by Sir Ernest Gowers. 8vo., 8½ in. × 5½ in., pp. vi + 94, London, H.M.S.O. 1948. Price 2*s.* 0*d.* net.

Sir Ernest Gowers wrote this little book at the request of the Treasury to help officials in their use of written English. Legal English is expressly excluded, because in laws and regulations the need for absolute exactness is paramount, and may have to be attained at the expense of easy readability. In all other official writing, clarity of expression is essential, and he shows how, with a little care in the choice of words, clarity can be obtained. The time of even the busiest official is not wasted by such care, for not only may it save unnecessary correspondence; clarity of expression means clarity of thought and therefore efficiency. Many examples are given, under the headings of " Correctness ", " The Choice of Words " (avoiding the superfluous word, choosing the familiar word, choosing the concrete word), " The Handling of Words " and "Punctuations ". The book makes amusing reading, but the reader who takes it to heart will be a better writer for it.

Meteorologists will be interested to see that Sir Ernest defends the use of " weather conditions ", as opposed to plain " weather ", against an attack in *The Times.* He writes: " *Weather conditions* imports a larger idea than *weather* does, at least in time of snow and frost. It embraces the conditions created by yesterday's weather and the likelihood of to-morrow's weather changing them." But he disqualifies the statement that " *blizzard conditions* had returned to the Midlands ": it was not blizzard conditions that had returned; it was a blizzard. He concludes that the Meteorological Department is too fond of " conditions ".

In scientific as in other forms of writing the clearest sentences are generally short, but at times the complexity of the idea to be expressed needs a long one. Sir Ernest quotes Mark Twain on how the author should deal with these exceptions:—

> "At times he may indulge himself with a long one, but he will make sure that there are no folds in it, no vaguenesses, no parenthetical interruptions of its view as a whole; when he has done with it, it won't be a sea-serpent with half of its arches under water, it will be a torchlight procession."

NEWS IN BRIEF

All British meteorologists, particularly those who served at Dunstable between 1942 and 1945, will be pleased to hear that the King has approved the appointment of Dr. Sverre Petterssen as an honorary C.B.E. in recognition of his war service with the Meteorological Office and Royal Air Force.

Dr. G. C. McVittie, a member of the Meteorological Research Committee, has been appointed to the new chair of Mathematics at Queen Mary College, University of London.

At Hamburg, the University Meteorological Institute, the centre for earthquake research, and the University Institute of Oceanography have been amalgamated to form the Geophysical Institute of the University of Hamburg. The address is Hamburg 13, Rothenbaumehausee 33.

WEATHER OF JULY 1948

During the first 16 days of the month pressure was persistently high to the west of the British Isles and low on the continent. From the 6th to the 9th the high pressure extended from the Azores at least to northern Greenland. Between the 17th and 21st depressions moved eastwards across and to the north of the British Isles. On the morning of the 21st, one of unusual intensity for July, covered Ireland with pressure about 986 mb. near the centre. As this depression moved away towards Norway an anticyclone spread from the south-west and passed across northern France and Belgium, reaching the Baltic and central Europe by the 24th. Pressure remained high to the east and north-east of the British Isles during the rest of the month.

Mean pressure for the month was above 1020 mb. around the Azores. It was above 1015 mb. from southern Europe across to the east coast of the United States and in the north-east of Greenland and Spitsbergen. There were areas slightly below 1010 mb. in the extreme south-west of the United States and Canada. Pressure was about 5 mb. above normal around Spitsbergen and Bear Island, but was generally not far from normal over Europe and North America.

The cool weather which set in at the end of June persisted until July 17. During this spell pressure was high on the north-east Atlantic and low to the east of the British Isles, depressions near Iceland moving south-east or south around the anticyclone. Cool winds prevailed, mainly between north and west, with rain especially on the 3rd, 4th, 7th, 8th, 10th–13th. A change occurred on the 17th when a depression approached west Scotland and subsequently remained almost stationary off the Hebrides, while secondaries moved north-east or north over the British Isles. Fairly heavy rain occurred in the southern half of England on the 17th ; temperatures rose to 79°F. at Gorleston on the 19th. On the 20th a deep depression approached west Ireland and subsequently moved rather quickly north-east across the country causing strong winds and gales at exposed places on the 21st; wind speed in gusts reached 71 m.p.h. at Pembroke and Holyhead, and 63 m.p.h. at Aberporth. According to the *Daily Telegraph* pleasure sailings in the west were cancelled or delayed and considerable damage occurred to fruit in the Vale of Evesham. By the 26th a wedge of high pressure extended south-west from an anticyclone over the Baltic to our south-eastern districts and later spread northward to influence the whole country. Temperatures rose rapidly, reaching or somewhat exceeding 86°F. locally in the south-east on the 26th and rising to 90°F. at a number of places on the 28th and 29th. During the last 3 days a trough of low pressure over our south-west districts moved slowly north and by the 31st covered the British Isles. Thunderstorms occurred in southern districts on the 28th–30th. On the 28th, at Marlborough, Wilts., houses and trees were struck by lightning; there were heavy squalls of wind at the peak of the storm and trees were uprooted. Heavy thunderstorms occurred in north-west England on the 31st; at Southport 1·68 in. of rain fell in 35 minutes. Considerable fog occurred on our south-west coasts and in the Channel on the 30th–31st.

Rainfall was considerably below the average over much of England and Wales and south-east Scotland but with local variation due to heavy falls in thunderstorms. The latter were severe locally in the period 28th–31st.

Mean temperature was very slightly below the average in most areas. The first 17 days were exceptionally cool but the last week was extremely hot. The maximum on the 28th was 94°F. at Mildenhall and South Farnborough and 93°F. at Kew Observatory, a record there for July; the 29th was the hottest July day at Southport since 1873 (90°F. at Hesketh Park). During the night of 28th–29th the screen temperature at Kew did not fall below 70°F., the highest minimum value recorded there, exceeding the readings of July 28, 1947 and July 13, 1923.

In spite of the brilliant sunshine during the last week, the duration of bright sunshine for the month was generally below the average in England and Wales but in Scotland and Northern Ireland there was some excess.

The general character of the weather is shown by the following table:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days' difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	95	34	−0·5	62	−3	93	35
Scotland ..	90	34	0·0	102	−2	103	29
Northern Ireland..	86	39	−0·4	97	−3	103	31

RAINFALL OF JULY 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·06	45	*Glam.*	Cardiff, Penylan ..	4·29	139
Kent	Folkestone, Cherry Gdns.	2·72	130	*Pemb.*	St. Ann's Head ..	2·44	94
,,	Edenbridge, Falconhurst	1·13	49	*Card.*	Aberystwyth	2·83	93
Sussex	Compton, Compton Ho.	1·83	65	*Radnor*	Bir. W. W., Tyrmynydd	2·63	64
,,	Worthing, Beach Ho.Pk.	1·18	58	*Mont.*	Lake Vyrnwy	..	..
Hants	Ventnor, Roy. Nat. Hos.	1·61	80	*Mer.*	Blaenau Festiniog ..	6·80	80
,,	Bournemouth	1·18	55	*Carn.*	Llandudno	1·55	69
,,	Sherborne St. John ..	1·32	59	*Angl.*	Llanerchymedd ..	2·75	96
Herts.	Royston, Therfield Rec.	1·38	55	*I. Man.*	Douglas, Boro' Cem. ..	2·48	81
Bucks.	Slough, Upton	·93	48	*Wigtown*	Port William, Monreith	2·64	94
Oxford	Oxford, Radcliffe ..	·85	36	*Dumf.*	Dumfries, Crichton R.I.	2·79	85
N'hant.	Wellingboro', Swanspool	1·28	56	,,	Eskdalemuir Obsy. ..	3·99	97
Essex	Shoeburyness	·97	53	*Roxb.*	Kelso, Floors	1·13	43
Suffolk	Campsea Ashe, High Ho.	1·35	59	*Peebles*	Stobo Castle	2·79	96
,,	Lowestoft Sec. School ..	1·63	72	*Berwick*	Marchmont House ..	1·56	51
,,	Bury St. Ed., Westley H.	1·64	66	*E. Loth.*	North Berwick Res. ..	1·23	48
Norfolk	Sandringham Ho. Gdns.	1·85	72	*Midl'n.*	Edinburgh, Blackf'd. H.	1·94	69
Wilts.	Bishops Cannings ..	·77	31	*Lanark*	Hamilton W. W., T'nhill	2·38	83
Dorset	Creech Grange.. ..	1·72	70	*Ayr*	Colmonell, Knockdolian	2·91	92
,,	Beaminster, East St. ..	1·29	50	,,	Glen Afton, Ayr San ..	..	..
Devon	Teignmouth, Den Gdns.	·70	30	*Bute*	Rothesay, Ardencraig	4·95	125
,,	Cullompton	1·71	64	*Argyll*	L. Sunart, Glenborrodale	4·15	89
,,	Barnstaple, N. Dev. Ath.	2·00	74	,,	Poltalloch	3·84	93
,,	Okehampton, Uplands	2·52	78	,,	Inverary Castle	6·66	134
Cornwall	Bude School House ..	2·06	84	,,	Islay, Eallabus ..	4·83	142
,,	Penzance, Morrab Gdns.	2·10	77	,,	Tiree	3·80	105
,,	St. Austell, Trevarna ..	2·27	68	*Kinross*	Loch Leven Sluice ..	3·55	123
,,	Scilly, Tresco Abbey ..	1·47	66	*Fife*	Leuchars Airfield ..	1·55	60
Glos.	Cirencester	·91	35	*Perth*	Loch Dhu	6·62	137
Salop.	Church Stretton ..	1·41	53	,,	Crieff, Strathearn Hyd.	2·76	93
,,	Cheswardine Hall ..	2·14	79	,,	Blair Castle Gardens ..	..	..
Staffs.	Leek, Wall Grange P.S.	2·26	70	*Angus*	Montrose, Sunnyside ..	2·50	95
Worcs.	Malvern, Free Library	·91	40	*Aberd.*	Balmoral Castle Gdns...	2·53	99
Warwick	Birmingham, Edgbaston	..	..	,,	Dyce, Craibstone ..	2·69	89
Leics.	Thornton Reservoir ..	1·24	50	,,	Fyvie Castle	2·93	90
Lincs.	Boston, Skirbeck ..	1·45	66	*Moray*	Gordon Castle	3·30	103
,,	Skegness, Marine Gdns.	1·73	79	*Nairn*	Nairn, Achareidh ..	2·46	96
Notts.	Mansfield, Carr Bank ..	1·28	49	*Inv's*	Loch Ness, Foyers ..	5·25	174
Ches.	Bidston Observatory ..	2·58	100	,,	Glenquoich	7·92	123
Lancs.	Manchester, Whit. Park	2·58	78	,,	Fort William, Teviot ..	7·05	144
,,	Stonyhurst College ..	2·49	64	,,	Skye, Duntuilm ..	4·16	111
,,	Blackpool	2·06	71	*R. & C.*	Ullapool	2·30	75
Yorks.	Wakefield, Clarence Pk.	1·41	56	,,	Applecross Gardens ..	4·65	116
,,	Hull, Pearson Park ..	·83	35	,,	Achnashellach	5·61	115
,,	Felixkirk, Mt. St. John	1·59	58	,,	Stornoway Airfield ..	2·60	90
,,	York Museum	1·19	47	*Suth.*	Lairg	1·84	59
,,	Scarborough	1·49	61	,,	Loch More, Achfary ..	7·02	131
,,	Middlesbrough.. ..	·79	31	*Caith.*	Wick Airfield	1·74	66
,,	Baldersdale, Hury Res.	·90	28	*Shet.*	Lerwick Observatory ..	3·22	141
Norl'd.	Newcastle, Leazes Pk. ..	·84	33	*Ferm.*	Crom Castle	3·51	101
,,	Bellingham, High Green	·79	24	*Armagh*	Armagh Observatory ..	2·46	85
,,	Lilburn Tower Gdns. ..	·90	36	*Down*	Seaforde	2·63	82
Cumb.	Geltsdale	2·40	70	*Antrim*	Aldergrove Airfield ..	2·51	90
,,	Keswick, High Hill ..	3·17	83	,,	Ballymena, Harryville..	3·33	97
,,	Ravenglass, The Grove	2·20	59	*Lon.*	Garvagh, Moneydig ..	2·99	92
Mon.	Abergavenny Larchfield	·71	29	,,	Londonderry, Creggan	4·80	131
Glam.	Ystalyfera, Wern House	3·86	84	*Tyrone*	Omagh, Edenfel ..	3·41	100

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, MARCH 1948

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily Mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1027·6	+14·7	71	33	55·6	40·3	47·9	+4·8	43·4	82	5·9	0·58	−1·11	7	4·4	37
Gibraltar	1025·1	+8·0	75	49	65·7	56·8	61·3	+3·7	57·6	83	7·0	0·69	—	7	5·0	42
Malta	1024·0	+9·8	70	44	61·5	49·5	55·5	−1·6	53·7	72	5·3	0·71	—	5	8·2	69
St. Helena	1014·5	−0·1	81	61	74·3	62·6	68·5	+3·0	62·6	95	7·1	4·82	+0·70	18	—	—
Freetown, **Sierra Leone**	1010·8	+1·6	90	72	85·7	76·6	81·1	+0·2	76·7	81	4·5	0·28	−0·88	2	7·8	65
Lagos, Nigeria ..	1010·4	+1·5	94	67	91·0	72·2	81·6	−1·8	77·3	79	6·2	2·15	—	6	5·3	44
Kaduna, Nigeria ..	1009·1	—	99	61	92·0	67·1	79·5	−2·1	59·4	24	4·3	0·11	−0·43	1	7·4	62
Chileka, Nyasaland	1012·7	−0·2	87	65	83·1	67·2	75·1	+1·6	70·3	77	5·9	4·68	−1·91	12	6·2	51
Lusaka, Rhodesia ..	1010·3	−0·4	83	60	79·5	63·1	71·3	+1·0	65·6	87	8·0	6·41	+0·20	20	4·9	—
Salisbury, Rhodesia	1011·6	−0·5	82	58	76·8	60·7	68·7	+1·0	63·3	80	7·3	5·54	+0·84	23	5·1	42
Cape Town	1014·7	+0·2	89	50	77·4	58·5	67·9	−0·2	58·7	75	6·5	1·58	+0·70	11	—	—
Germiston, South Africa	1012·1	—	79	52	73·9	57·6	65·7	—	58·2	83	6·7	3·98	—	15	6·3	52
Mauritius	1012·6	+0·7	90	69	86·5	72·5	79·5	+1·5	73·4	79	5·2	3·62	−4·97	25	8·0	65
Calcutta, Alipore Obsy.	1010·3	+0·2	100	57	92·2	69·2	80·7	+0·5	69·3	76	2·4	4·82	+3·44	5	9·0	75
Bombay	1010·0	−0·9	95	69	89·3	73·5	81·4	+1·9	71·9	77	1·1	0·00	−0·02	0	9·6	80
Madras	1010·7	−0·2	99	67	91·3	74·2	82·7	+1·6	74·5	79	2·9	0·00	−0·34	0	10·3	86
Colombo, **Ceylon** ..	1010·2	+0·1	92	70	89·2	73·7	81·5	−0·3	73·9	85	4·3	2·63	−1·65	7	9·2	76
Singapore	1009·4	−0·3	92	72	87·5	74·2	80·9	−0·3	76·4	85	7·1	10·00	+2·60	19	—	—
Hongkong	1017·1	+1·1	84	50	73·2	63·5	68·3	+5·0	64·2	82	—	0·80	−2·14	8	3·9	32
Sydney, N.S.W. ..	1017·2	+0·9	88	54	74·7	61·2	67·9	−1·4	61·6	71	5·3	3·61	−1·37	14	6·7	55
Melbourne	1017·7	+0·8	90	42	71·0	50·7	60·9	−3·6	53·5	60	5·3	0·29	−1·89	8	7·5	61
Adelaide	1019·8	+2·7	93	50	75·5	57·0	66·3	−3·6	55·8	45	4·4	0·27	−0·75	3	8·5	61
Perth, W. Australia	1015·5	+0·2	95	56	88·0	65·5	76·7	+5·5	66·0	51	1·0	2·35	+1·54	6	8·6	70
Coolgardie	1017·3	+2·4	98	52	85·5	61·1	73·3	+1·4	60·3	55	3·2	0·08	−0·86	2	—	—
Brisbane	1014·3	−0·1	91	62	82·7	67·5	75·1	+0·8	69·0	72	5·3	6·13	+0·36	12	7·6	61
Hobart, Tasmania																
Wellington, **N.Z.** ..	1015·7	−1·5	75	47	67·4	55·0	61·2	+1·9	57·1	74	7·3	2·86	−0·47	8	6·3	51
Suva, Fiji	1010·0	+1·6	88	70	84·4	73·9	79·1	−1·0	75·8	86	6·8	14·60	+0·11	25	5·7	47
Apia, Samoa ..	1009·3	+0·3	90	72	87·4	74·5	80·9	+0·5	77·6	78	6·3	3·33	−10·38	19	7·4	61
Kingston, Jamaica																
Grenada, W. Indies	1013·6	+0·6	86	67	84·1	74·0	79·1	+1·3	73·8	78	7·2	2·21	−0·45	20	—	—
Toronto	1018·9	+1·6	62	−1	39·9	24·3	32·1	+2·5	26·2	—	7·1	2·58	+0·17	13	4·9	41
Winnipeg	1017·1	−2·1	42	−33	21·9	2·9	12·4	−2·6	6·0	—	6·0	0·77	−0·39	10	5·8	49
St. John, N.B. ..	1018·5	+4·4	55	−8	33·8	17·6	25·7	−2·7	21·0	—	5·9	4·64	+0·10	18	4·9	41
Victoria, B.C. ..	1013·9	−2·0	58	25	48·9	33·0	40·9	−2·6	35·1	94	6·1	3·43	+1·00	11	5·0	42

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WASHINGTON CODES

BY E. G. BILHAM, B.SC., D.I.C.

At the 12th Conference of Directors held in Washington in September 1947, a large number of changes in the codes, specifications and procedures used in synoptic meteorology were recommended. It was also recommended that the new codes, specifications and procedures should come into use throughout the world on January 1, 1949. This date will therefore mark a red letter day in the history of synoptic meteorology. A " new order " will come into being which will profoundly affect almost every detail of the work of observers, plotters and forecasters in every part of the world. The purpose of this note is to give a brief outline of the principal changes, and to indicate the steps which are being taken in the Meteorological Office to prepare for the changes.

Index numbers of stations.—All stations will have new index numbers. The complete index number of every station will consist of five figures which may be written IIiii. The first two figures II represent a " block number ", which is generally the same for all stations in the same country, or (in the case of countries which cover a very large area) part of a country. For example, the block number for Great Britain and Ireland is 03. The last three figures iii represent the " national number " allotted to the station by the service concerned. In most forms of message only the national number will appear, but in collective messages groups of the form 999II will be used to indicate that the stations whose reports follow are in block II.

Forms of message.—Symbolic forms, either entirely new or different from those at present used in the Meteorological Office, will be brought into use for the following:—

- Synoptic reports from land stations
- Synoptic reports from ships (with " full ", " abbreviated " and " short " versions)
- Abbreviated reports for aviation
- Reports of sudden changes (MMMMM and BBBBB)
- Upper air reports
- CLIMAT messages

Reports from transport aircraft
Route and flight forecasts
Terminal and area forecasts

Minor modifications have also been made in the pilot-balloon code. The Combined Analysis Code (C.A.C.) has been adopted without substantial change under the name International Analysis Code (I.A.C.) with a shortened version for marine use, known as I.A.C. FLEET. The code known as CAW-C will continue in use for reporting observations made on meteorological reconnaissance flights.

Changes will also be made in many of the tables of specifications used for coding the various elements included in the messages. Those which affect the synoptic code are briefly referred to below.

New code for synoptic reports.—In view of its special interest, and its importance as the basic form from which other codes used for surface reports are derived, we give here the symbolic form (SYNOP) of the Washington Code for synoptic reports from land stations.

$$(999\mathrm{II})\quad \mathrm{iiiT_dT_d}\quad \mathrm{Nddff}\quad \mathrm{VVwwW}\quad \mathrm{PPPTT}\quad \mathrm{N_hC_LhC_MC_H}$$

$$(6\mathrm{japp})\quad (7\mathrm{RRjj})\quad (8\mathrm{N_sCh_sh_s})\quad (9\mathrm{S_PS_Ps_ps_p})$$

The first five groups are " universal " groups, that is to say they will always appear in the message. The groups in brackets, each of which begins with a different indicator figure, are " drop-out " groups the use of which is governed either by regional agreements or by meteorological circumstances. In the European Region, the 6-group which contains the barometric characteristic and tendency will be obligatory, and the 7-group will be used at 0600 G.M.T. to report night rainfall and night minimum temperature, and at 1800 G.M.T. to report day rainfall and day maximum temperature. The 8-group gives additional details of cloud layers significant for aviation and drops out when there is no cloud of amount more than a trace below 20,000 ft. The 9-group is used to report special phenomena and to amplify the details of present and past weather.

Meanings of symbols.—In the following list changes in specifications or practice are indicated in italics

iii = Station national number (*new series*).
T_dT_d = Dew point (for temperatures below freezing point this is the temperature of saturation *over supercooled water*).

N = Total amount of cloud *in oktas* (*eighths*)..
dd = Surface wind direction *to nearest ten degrees* (*i.e. scale* 01–36).
ff = Surface wind speed *in knots*.

VV = Horizontal visibility—*new scale, over most of the range the code number being equal to the visual range in furlongs* (200 *m.*)
ww = Present weather (*revised code*).
W = Past weather.

PPP = Pressure at mean sea level in millibars and tenths (initial 9 or 10 omitted).
TT = Dry-bulb temperature.

N_h = Amount *in oktas* of cloud the height of which is given by h.
C_L = Form of low cloud (*revised code*).
h = Height of low cloud.
C_M = Form of medium cloud (*revised code*).
C_H = Form of high cloud (*revised code*).

j = Symbol agreed on a regional basis—in the European Region state of ground E (*revised code*) is reported at 0600 and 1800 and a_x, detailed characteristics of barograph trace (*an entirely new code*), at other synoptic hours.
a = Characteristic of tendency.
pp = Barometric tendency in *tenths* of millibars.

RR = Rainfall (0600–1800 and 1800–0600 G.M.T. in European Region).
jj = Symbol agreed on a regional basis—in the European Region *minimum temperature* (1800–0600) at 0600, *maximum temperature* (0600–1800) at 1800.

N_s = Amount *in oktas* of significant cloud.
C = Type of significant cloud.
h_sh_s = Height of base of significant cloud—over most of the range h_sh_s is height in *hundreds of feet.*

$S_PS_Ps_ps_p$ = *Special phenomena and amplifying details of past and present weather.*

The ship's code is basically similar to the land code, the first group iiT_dT_d being replaced by the usual time and position groups $YQL_aL_aL_a$ $L_oL_oL_oGG$ and the 6-group being changed to d_sv_sapp, where d_s and v_s give the ship's course and speed. There is an additional drop-out group $oT_sT_sT_dT_d$ for reporting sea temperature and dew point and a group 1d $d_wP_wH_w$ for reporting the direction, period and height of waves, replacing the old sea-and-swell group. Provision is also made for reports of ice conditions. British selected merchant ships will not use the 8-group and the 9-group but these groups will appear in reports from ocean weather ships.

New charts.—A new series of plotting charts will be introduced, printed in light ochre and pale blue, the colours recommended in a Washington resolution. Specimens have already been tried at selected offices, most of which preferred the new ochre colouring to the familiar green. On the new charts the station numbers will be over-printed in light blue with the block boundaries indicated by pecked lines and the block numbers printed in a small square near the middle of each block.

New and revised publications.—Full details of the new codes and procedures will be set out in a new publication called "Handbook of weather messages, codes and specifications". The Handbook will be issued in three parts. Part I will contain the transmission schedules of all weather messages emanating from Great Britain, Malta, Gibraltar, the Middle East and the British Zone of Germany, together with the index numbers, heights and co-ordinates of stations appearing in the transmissions. Part II will give the codes and specifications in full detail. Part III will contain instructions for coding, decoding, plotting and recording, together with new humidity tables. The old *Pocket Register* (Form 2003) will be replaced by a new *Daily Register* of foolscap size (Form 2050) in which the columns are arranged in the same order as the elements in the synoptic message. At the same time a pocket-size pad will be introduced for the initial entry of observations so that the Register does not have to be taken out of doors when making the outdoor observations. New editions of " Cloud forms " and of the " Instructions for the preparation of weather maps " (Form 2459) will also be issued. Observers at auxiliary stations will be provided with new versions of the *Register of Observations* (Form 2611) and "Abbreviated weather reports for aviation " (Form 2612). All other forms, etc., related to synoptic procedure will be similarly revised.

Concluding note.—It will be clear from the foregoing that a very special effort will be called for by everyone associated with the synoptic weather service when the " new order " is brought into being. The Directors and technical experts of all countries laboured unremittingly over a period of three years to solve the problems presented by the code situation at the end of the war. Those responsible for the implementation of the Washington resolutions have done all that foresight and planning can do to make the changeover as easy as possible. It now remains for meteorologists and assistants of all grades to give their whole-hearted co-operation in carrying out this great and far-reaching operation. We are perhaps all inclined to look for demerits rather than merits in things which are new and strange, but there is little doubt that as we settle down under the new procedures we shall appreciate the unification that has been achieved and find that we can do our work better and with more satisfaction with these brave new tools.

INTERNATIONAL METEOROLOGICAL ORGANIZATION

Telecommunications Sub-Commission Meeting in London, July 1948

BY C. V. OCKENDEN, B.SC.

An account of the International Meteorological Organization (I.M.O.) was published in the *Meteorological Magazine* for March 1947 and reference was made to the recent Conference of Directors in Washington in the issues for January and February 1948. Resolution No. 220 of the Washington Conference directed that each I.M.O. Regional Commission should establish a Sub-Commission charged with the duties of organising the meteorological telecommunications within the region, co-ordinating transmissions between adjacent regions and compiling information for insertion in the appropriate publications of I.M.O. After the meeting in Paris last April of the European Commission, the President invited all countries in Europe (Region VI) to nominate a representative to serve on the Sub-Commission which was summoned to meet in July.

Meetings were held from July 5 to July 10 at Lancaster House, St. James', London, and delegates from about a dozen countries were welcomed by the Secretary of State for Air, Mr. Henderson, in the large Conference Room (this was originally one of the state rooms whose splendours were described by Disraeli as being " not unworthy of Vicanza "). The Secretary of State remarked that the science of meteorology cannot be limited by boundaries of political or natural geography, and he stressed the fact that without first-rate communication facilities it would be impossible to construct adequately and promptly the many charts now required not only for day-to-day forecasting but also for forecasting research.

The work of the Sub-Commission consisted to a large extent in examining problems to which only partial and provisional solutions had been found at previous Regional and International Civil Aviation Organization (I.C.A.O.) meetings. M. Leclercq (France) was elected Chairman and two working panels were formed, one under the chairmanship of Mr. Ockenden (United Kingdom) to deal with the more technical items on the agenda, and the other under the chairmanship of M. Godart (Belgium) to study items concerning (*a*) the preparation of handbooks, and (*b*) changes in procedure which would be necessary as a result of recent I.M.O. decisions and the introduction of new codes in January next. The Conference did not learn until the second day that the Danish representative Dr. Lykke and his secretary, Mlle. Doellner, were passengers in the Swedish aircraft which was involved in the collision at Northolt on the previous Sunday. Many delegates felt that they had lost a personal friend in the tragic death of Dr. Lykke and a message of sympathy was sent to Copenhagen. It was also a matter of regret that delegates from U.S.S.R., Czechoslovakia, Hungary and Romania were unable to arrive for the discussions which included the formulation of schemes to extend the exchange of data by means of teleprinter circuits to central and eastern Europe. The western European meteorological teleprinter network has proved so successful that the setting-up of similar networks to cover the whole of Europe can only be a matter of time. As an interim measure plans have been laid for Norway, Sweden, Denmark, Poland, Czechoslovakia and Italy to be connected to the western network at suitable centres as soon as their internal teleprinter circuits are sufficiently developed.

An important decision was reached concerning the European terminal which should handle the exchange of data with North America. It was agreed that radioteleprinter working has now become sufficiently reliable to be adopted in preference to the much slower W/T channels, and it was recommended that, commencing July 1, 1949, Dunstable, England, should assume responsibility for the exchange of data with New York and for re-diffusing American data to other European countries both by W/T and teleprinter broadcasts. The Conference also considered that there should be a cable stand-by so that a skeleton exchange can be maintained in the unlikely event of all radio communication being interrupted by a radio " blackout ".

Other recommendations concerned the requirement for still further standardization of messages and procedure, the possible amalgamation of national W/T broadcasts from neighbouring small countries and the formation of a panel to study the international aspects of facsimile transmissions.

Delegates were invited by H.M. Government to a reception in the Air Ministry Air Council Room on one evening, and a visit was arranged to the Central Forecasting Office at Dunstable on the afternoon of July 8.

THE SEA-GOING METEOROLOGIST

BY A. H. GORDON, M.S. (Pasadena)

The accuracy and detail of all weather forecasts at present prepared in this country are very largely dependent on the receipt of routine information from the Atlantic Ocean. The overall efficiency of the meteorological service, as supplied to the B.B.C. and the press for issue to shipping and to the public and as supplied to the services and civil aviation, is thereby closely related to the quantity, quality and regularity of information received from the ocean to our west.

Before the war information received from the Atlantic was derived almost entirely from merchant ships which necessarily tended to concentrate on more or less fixed tracks thus leaving considerable blank areas such as to the west of Ireland and Scotland and to the south of Iceland and Greenland.

With the return of peace it was realised generally that the receipt of observations from ships pursuing courses along narrow sea lanes was not, in itself, sufficient measure to meet the superior and more accurate meteorological service required to supply post-war world aviation and other needs. Accordingly, it was decided by the International Civil Aviation Organization supported by the International Meteorological Organization to recommend the establishment of ocean weather ships at fixed positions on the oceans from whence they would transmit at regular agreed intervals full surface and upper air meteorological information. It is emphasised that this does not in any way belittle the value of observations from merchant ships but supplements them in areas which would otherwise be devoid of any information whatsoever.

Great Britain's contribution to this international plan has been the establishment of four ocean weather ships to maintain between them a continuous watch at stations 53°50′N. 18°40′W. and 60°N.20°W., commonly known as stations JIG and ITEM, in the North Atlantic.

There are two great advantages in obtaining in this way information additional to that obtained from normal shipping. First, the information is derived from positions well outside the normal shipping lanes and thus covers what would otherwise be a blank spot. Secondly, since the ship is stationary, the sequence of weather at that position can be supplied to the meteorologist ashore. A knowledge of the weather sequence at a given station on the synoptic chart is an essential factor in chart analysis and therefore in the accuracy of any forecasts subsequently prepared. This element of sequence does not possess the same value when obtained from a moving ship. In particular the accuracy of the barometric tendency is reduced even though allowance is made for the ship's movement across the isobars.

Apart from the supply of surface observations from these fixed positions in the eastern Atlantic the establishment of the ocean weather ships has provided facilities for the undertaking of upper air observations. It is clearly impracticable for this type of work to be undertaken by other ships during the course of their normal voyages; thus the ocean weather ships provide the sole means by which the supply of this most important information can be effected.

The sea-going meteorologist plays an essential part in the highly complex organization of the meteorological service. His observations are awaited with great expectancy ashore. On the majority of occasions these observations are, without exception, the most important on the chart and quite far-reaching decisions involving all manner of service exercises and flights throughout the entire country may depend upon the information they contain. The issue of gale warnings which results in the taking of widespread precautionary measures for the safety of life and property both at sea and on land cannot function efficiently unless based on reliable information from the vital ocean areas through which storms are moving or in which they are developing.

In addition to partaking in the routine surface and upper air observational work the sea-going meteorologist has the opportunity of investigating a number of problems relating to instrumental and synoptic problems at sea. Such investigations present a new field which has hitherto only been touched upon lightly.

The ocean weather ships, however, provide the material facilities for studying the various aspects of marine meteorology in the field so that considerable contributions can be made to our knowledge of this subject and of meteorological science as a whole.

The boundary conditions governing the physical processes of the atmosphere are considerably different over the oceans from over land. Surface friction, heat exchange and lack of topographical influences are all factors which make meteorological conditions different at sea from over land. There is a great deal of interesting and useful research to be done by the sea-going meteorologist during the course of his periodic expeditions into the heart of the Atlantic.

If the centre of a depression should pass over the ship's position opportunity is offered for first-hand eye-witness studies to be made by the meteorologist of certain features in nature to which it has not been possible in the past to devote similar specialist attention. Likewise, if any unusual local phenomenon such as a waterspout is observed nearby it might be approached and a special close examination made under circumstances which it has not been possible to provide previously.

On the more practical side the sea-going meteorologist may be interested in such matters as the design, accuracy and exposure of the meteorological instruments aboard the ship, or he may be an enthusiast for the technical aspects of the radar and radio-sonde equipment.

A word on the lighter side might be included. There are, of course, few healthier pursuits than life aboard ship at sea. Cigarettes and other goods are obtainable at duty-free prices. Recreation in off-duty hours can at times be taken in the form of rubber-dinghy rowing while even races can be indulged in. There are possibilities of swimming in the summer months while sunbathing may be enjoyed on deck when the weather permits. Cinema shows and bridge provide indoor recreation. Attempts at deep-sea fishing have been made but with little success so far. There is a good library and radio receivers are available for entertainment reception. There should be little time during the 28-day voyage which cannot be fully and interestingly utilised. And then, at the end of their period on station, there is the exhilaration of being homeward bound—the thrill of which to a seaman never seems to lessen—coupled with the realization of a useful job well done. And at the end of the voyage 15 days leave provides a welcome and well earned diversion.

Thus, to the meteorologist who is keen to undertake a new and somewhat unusual task that is away from the normal run, combining work of the highest value and importance with rather different recreational opportunities, then the job of sea-going meteorologist aboard an ocean weather ship is the sort of change that should suit him best.

THE DEVELOPMENT OF THE METEOROLOGICAL OFFICE RADAR REFLECTOR, MK. II B

BY O. M. ASHFORD, B.SC., A.INST.P. AND H. J. FERRER, B.SC.

Introduction.—Since the introduction of the radar method of measuring upper winds,* development work has been directed to improving the radar reflectors. This report describes the work to date which has resulted in the introduction of the Mk. II B reflector.

Requirements.—A radar reflector for use with the GL Mk. III (A.A. Radar No. 3 Mk. 2/4) set should meet the following requirements:—

(*a*) It must be an efficient reflector of radio waves of 10-cm. wave-length.
(*b*) The aerodynamic drag must be as low as possible.
(*c*) The weight must be as low as possible.
(*d*) The assembly procedure must be straightforward, requiring no ancillary equipment.
(*e*) The dimensions when packed for storage must be as small as possible.
(*f*) The cost must be as low as possible.

The most serious disadvantages of the existing paper reflectors fall under headings (*b*) and (*e*). The storage dimensions and aerodynamic drag are so large that it would be quite impracticable to handle a similar reflector of larger size, which would be needed for extending the maximum obtainable range.

The ideal arrangement would be to have an electrically conducting balloon. Two alternatives were considered: to have the balloon coated with a metallic paint or to have the balloon fabric impregnated with an electrically conducting substance such as carbon. In both cases the chief difficulty was that as the balloon expanded (in a normal ascent its diameter increases from 6 ft. to 16 ft. or more) the electrical resistance of the balloon would increase beyond the allowable limits.

The next possibility would be to have the reflector inside the balloon. No experimental work was done on this because the bursting height of the balloon would be adversely affected by the attachments required to hold the reflector stretched in position. A reflector of sufficient rigidity in itself, yet capable of being passed through the balloon neck (internal diameter about 1 in.) would tend to be too expensive.

For 100-gm. balloons which expand to about 6-ft. diameter, a shroud reflector made of metallised nylon mesh has been proved satisfactory by the Admiralty. The area of a similar reflector for a 350-gm. or 500-gm. balloon would be about 50 sq. yd., and the cost would be prohibitive.

In view of these considerations it was concluded that the most hopeful line of attack would be to develop a corner reflector with the planes made of wire

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* London, Meteorological Office, Measurement of upper winds by radar methods. London, 1944.

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I.M.O. EUROPEAN TELECOMMUNICATIONS SUB-COMMISSION

Mr. Arthur Henderson, Secretary of State for Air, opening the conference at Lancaster House

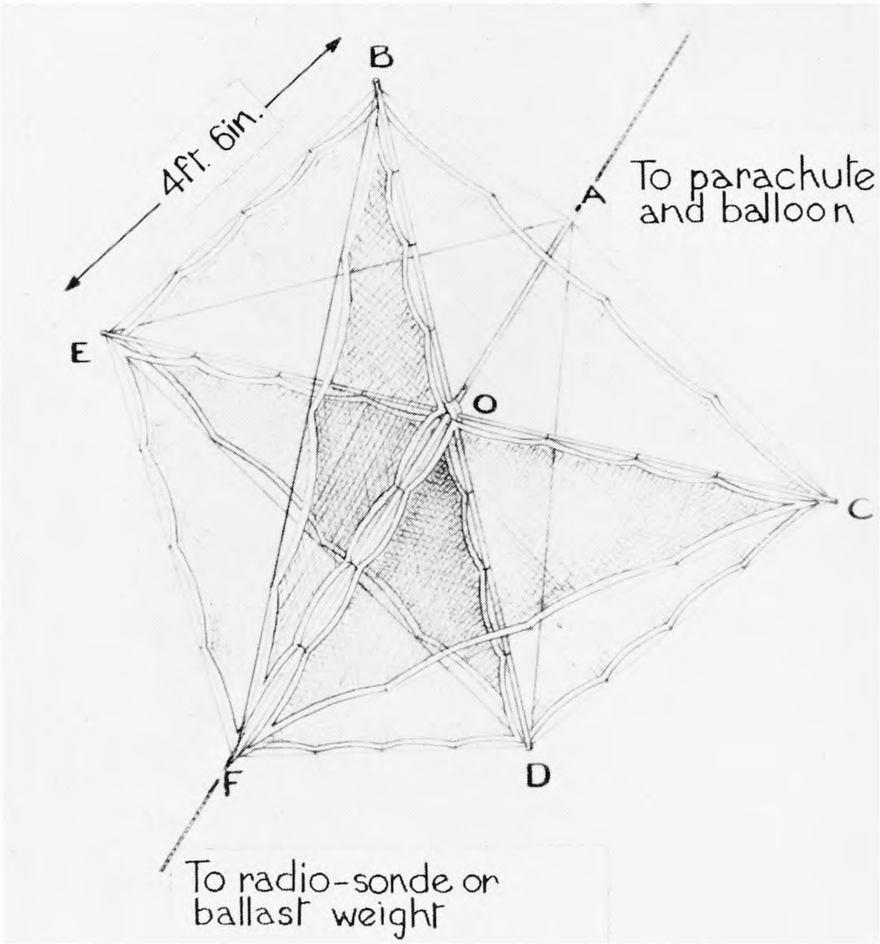
B
4ft. 6in.
To parachute and balloon
A
E
O
C
F
D
To radio-sonde or ballast weight

FIG. I—MK. II B REFLECTOR

mesh or metallised nylon mesh. The chief difficulty with the wire mesh was to find a suitable knitting machine—a woven mesh would not lend itself so readily to being folded into a small pack and subsequently opened out to make a smooth taut plane. Some experiments have been made with knitted wire mesh but so far the results have not been very satisfactory.

Radar reflector Mk. II B.—The new reflector which is now in large-scale production is shown in Fig. 1. The square plane BCDE and the triangular planes BOF, COF, DOF and EOF are made of nylon mesh, approximately 5 meshes to the inch, impregnated with silver by the " sucalising " process. The electrical resistance between any two points on a plane 1 ft. apart is nowhere greater than 10 ohms. The planes are bound along the edges with a cambric tape and stretched on a framework of duralumin tubing. Additional support is provided by a number of bracing wires, EFC, BFD, EAC, BAD and BCDF, which may be brought to the required tension after assembly by rotating the rod AO. The rod AO is held in the final position by inserting a split pin through holes in the rod and the central boss at O. The side of the top square is 4 ft. 6 in. in length. When packed for transit, the dimensions are 40 in. × 2¾ in. × 1½ in. compared with 42 in. × 42 in. × ⅝ in. for the 3-ft. paper reflector. The reflector weighs 790 gm., only 30 gm. more than the 3-ft. reflector.

In spite of the increased dimensions, the aerodynamic drag of the Mk. IIB reflector is appreciably less than the 3-ft. paper reflector because of the mesh construction. This point is illustrated in Fig. 2, in which the rate of ascent is plotted as a function of the free lift for the Mk. IIB reflector and the 3-ft. paper reflector. " Free lift " is here defined as the weight the balloon will just lift in addition to the attached load.

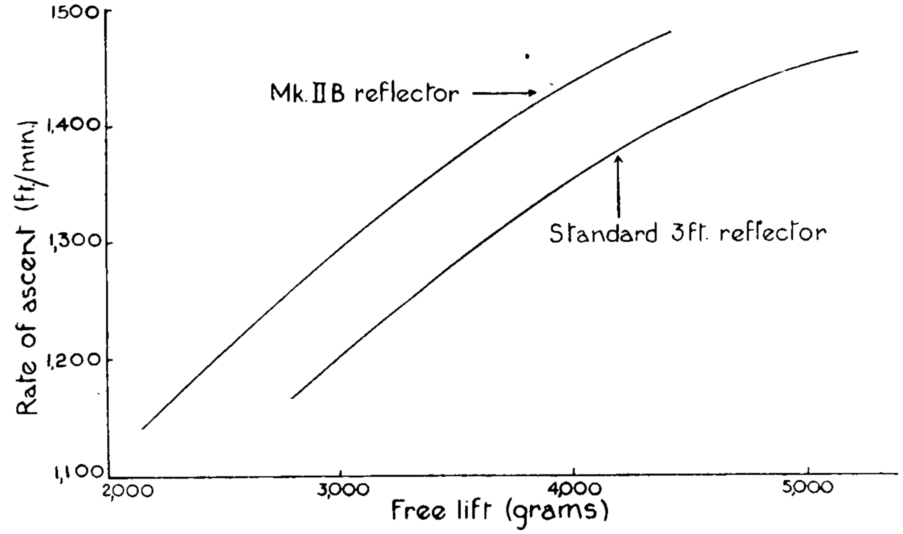

FIG. 2—RATE OF ASCENT OF MK. II B REFLECTOR AND STANDARD PAPER REFLECTOR

To assess the performance of the new reflector, a series of comparison flights was made using a 3-ft. paper reflector as a standard. The results of a typical flight are shown in Fig. 3, in which the mean signal/noise ratio is plotted against the slant range. The trials were made with a GL Mk. III set and the results given in Fig. 3 were obtained when the set was working at high efficiency.

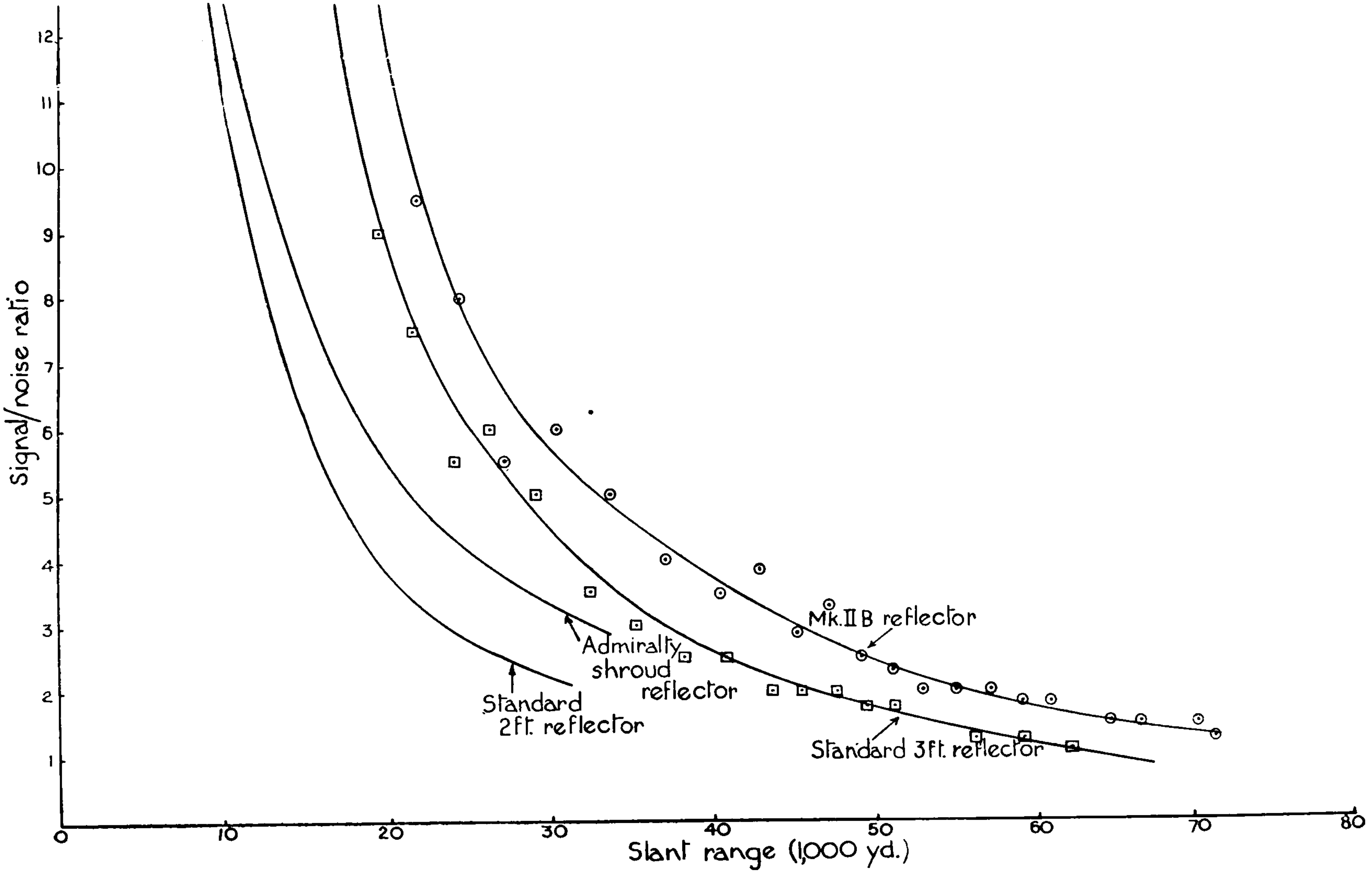

FIG. 3—SIGNAL/NOISE RATIO AT DIFFERENT RANGES

The curves in Fig. 3 for the 2-ft. paper reflector and the Admiralty " shroud " reflector are based on Figs. 3 and 4 of R.R.D.E. Report No. 311*. To allow for the dependence of the signal/noise ratio on the set efficiency and the method used for estimating its mean value, the R.R.D.E. results were brought to roughly the same standard as the other Fig. 3 curves by using the 3-ft. reflector as a standard of reference. Too much weight should not therefore be attached to the numerical values of signal/noise ratio given in Fig. 3, but the relative position of the various curves are considered to be fairly representative.

It will be seen that, although the Mk. IIB reflector is appreciably better than the 3-ft. paper reflector, the improvement is not so great as might have been expected (the range for a given signal/noise ratio should be proportional to the linear dimensions). This is partially due to the various planes not being electrically bonded. In the original Mk. IIB reflectors, the cambric tape was metallised and the triangles were therefore in direct electrical contact with the top square. Unfortunately the cost of metallising the tape was excessive and in the production model it is left plain. It is estimated that an improvement of 10 per cent. in the signal/noise ratio would be achieved by bonding the planes to each other.

The assembly of the Mk. IIB reflector is complicated by the necessity for having the tensioning wires. The efficiency of a corner reflector falls off very rapidly if the surfaces are not sensibly plane and if the angles differ by more than a degree or so from right angles. It was found that a good tension was essential for the mesh type of reflector and the present method is the simplest yet devised.

Conclusion.—The Mk. IIB reflector is much better than the older type as regards drag and storage dimensions and its performance is slightly better. Further improvement may be achieved by some method of electrically bonding the planes, and a simpler method of providing adequate tension is also desirable.

OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

Annual Report of the Director of the Meteorological Office presented by the Meteorological Committee to the Secretary of State for Air for the year April 1, 1947, to March 31, 1948.

This report contains an account of the important progress made during the past year towards placing the Office on a peace-time basis.

The reorganization of the Office in accordance with the White Paper on the Government Scientific Service (Cmd. 6679) was almost completed. In view of the increased responsibilities of the Meteorological Office the Headquarters was strengthened and now includes a Principal Deputy Director, three Deputy Directors and nine Assistant Directors.

Various steps were taken to make the service provided by the Meteorological Office for the general public closer and more effective. Apart from the forecasts and warnings broadcast by the B.B.C. a system was introduced for providing the control offices of British Railways with advance notification of weather likely

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*ALLWOOD, H. I. S. AND BEECHING, G. H.; The suitability of existing types of balloon-borne reflectors for the measurement of wind speeds by means of equipment Radar A.A., No. 3 Mk. 2/4. *R.R.D.E. Research Rep. Malvern, Worc.* No. 311, 1946.

to interfere with passenger and goods services. In another scheme arrangements were made to provide snow warnings to County Surveyors and Divisional Road Engineers throughout the country. Further measures to assist the national economy are under discussion with the Departments concerned.

Among the extensions of services for the Royal Air Force and civil aviation was the provision at Malta and Shaibah of facilities to enable over-flying aircraft to discuss the weather situation with the duty forecaster by radio-telephony.

The international scheme for the establishment of 13 weather stations in the North Atlantic is proceeding. The first British ocean weather ship took up her station in August 1947 and the remaining three were all commissioned by January 1948.

Certain Colonial Meteorological Services which came under Air Ministry control during the war were handed back to the local Governments. All necessary assistance was given to these and other Colonial Services to enable them to function efficiently.

The Meteorological Office took a leading part in the work of the International Meteorological Organization, the Director of the Office being President of the Organization throughout the year. Several members of the Office attended the meetings of the Organization held in Toronto and Washington at the end of the summer. To increase the status of the International Meteorological Organization it was agreed to replace it by a World Meteorological Organization supported by an intergovernmental convention.

Research work was undertaken on an extensive scale. It is formulated by the Meteorological Research Committee and carried out by the Office research organization. Of the research work performed may be mentioned:—

(*a*) an exhaustive study of the distribution of wind all over the world up to the heights of over 45,000 ft. necessary for air-route planning,

(*b*) other research for aviation concerned with the means of enabling aircraft to avoid turbulent clouds, means of reducing the risks of ice accretion, and the navigational technique known as pressure-pattern flying,

(*c*) forecasting research using circumpolar weather maps and further study of the physical principles of the atmosphere (detailed studies of errors in routine forecasts were made focussing attention on the inadequacies of current knowledge),

(*d*) research for agriculture on the meteorology of the air near the ground especially in connexion with its water-vapour content,

(*e*) in the field of meteorological instruments work on balloons to carry instruments to a height of 100,000 ft. and on instrumental means of measuring cloud height in daylight and visibility at night.

PROFESSIONAL NOTES

No. 91. *The vertical gradient of wind velocity in the lowest layers of the atmosphere.* By N. K. Johnson, K.C.B., D.Sc.

This paper contains almost unchanged two Porton reports dated February 14, 1923, and March 19, 1925.

The first report shows that in temperature-lapse conditions the wind velocity in the lowest 3 metres of the atmosphere can be expressed in the form

$$u = A \log_{10}(z + c) + B,$$

where u is wind velocity, z is height, and A, B and c are constants. This logarithmic law was also found to hold up to heights of 305 m. above the ground.

In temperature-inversion conditions the velocity gradient is much steeper than when temperature decreases with height and approximates to the logarithmic law, although not as closely as in the case of a temperature lapse.

The second report is an endeavour to fit a more tractable expression, of the form $u = Bz^m$, than the logarithmic law above, which was found to be rather inconvenient mathematically. Hourly values from autographic records made by three electrical cup anemometers at 5·0 m., 13·4 m. and 21·7 m. are compared with readings taken with delicate air meters (such as were used in experiments for the first report), and the two were found to be in satisfactory agreement. The value of m was found to vary from 0·08 with a temperature lapse of −0·1°F./m. to 0·26 with a temperature inversion of +0·18°F./m.

In a given temperature gradient, the value of m is found to be independent of the wind velocity provided the latter exceeds 6 m./sec. Below this wind velocity the value of m tends to increase. It is suggested that this result is due to the reduced eddy viscosity at low wind velocities.

LETTERS TO THE EDITOR

High pilot-balloon ascents at Oakes Field, Nassau, Bahamas

In the November 1947 issue of the *Meteorological Magazine*, Mr. J. C. W. Wickham commented on high pilot-balloon ascents made at Piarco, Trinidad. The following notes on high pilot-balloon ascents made at Nassau, Bahamas, during the period October 1946 to December 1947 might prove of interest in so far as Nassau, like Piarco, also lies in a maritime air mass.

Pilot-balloon ascents are made four times daily, as near as possible to 2200, 0400, 1000 and 1600 E.S.T. (0300, 0900, 1500 and 2100 G.M.T.), the results being included in the United States scheduled broadcast of synoptic and upper air data. Unless the occasion warrants it, e.g. during the presence of a hurricane, there is little divergence from these times, and it is frequently not possible to utilise the best conditions for balloon ascents.

The location of the station at Oakes Field airport is not too favourable for daylight ascents, since it lies on a low ridge on the northern side of a shallow valley running east-west across New Providence Island. Cloud forms rapidly over the ridge throughout the year after about 0900 E.S.T., irrespective of the direction of the wind in the lowest layers. Out of the 540 cases examined between July 1, 1946, and December 31, 1947, there were only 87 occasions in which a height of 18,000 ft. was reached at 1000 E.S.T.

Unless the cloud formation is typically stratocumulus in character there is normally a decrease of cloud towards 1600 E.S.T. There is a minimum cloudiness over the island around dawn and, during the summer months, ascents are taken between 0500 and 0600 E.S.T. whenever possible. The number of ascents up to or above 25,000 ft. during the period October 1946 to December 1947 were 48 at 1000, 50 at 1600, and 12 at 0600 E.S.T.

Although haze is common in summer, this does not present any serious hazard to high-altitude ascents. The one exception, during 1947, was the day

PILOT-BALLOON ASCENTS AT NASSAU, BAHAMAS, BETWEEN DECEMBER 1946 AND DECEMBER 1947

Date	Dec. 19 1946		Feb. 17 1947		Feb. 20 1947		Feb. 23 1947		Feb. 27 1947		Mar. 5 1947		Mar. 24 1947		Oct. 23 1947		Nov. 5 1947		Dec. 24 1947	
Time (G.M.T.) . .	2100		2200		1500		2100		2100		2200		2100		1600		2000		1500	
ft.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.
5,000	120	10	320	13	190	22	220	10	270	10	130	15	210	21	110	13	250	12	330	7
10,000	180	4	320	23	220	29	270	23	310	30	290	10	290	13	110	3	280	21	290	29
15,000	220	10	290	22	270	45	270	73	280	56	290	40	240	28	290	21	300	25	260	25
20,000	240	9	290	24	280	55	260	84	280	54	300	40	250	37	290	22	280	35	260	31
25,000	250	15	290	58	280	63			280	68	310	60	270	49	300	25	270	45	270	43
30,000	250	28	270	93					270	79	280	72	270	69	300	45	260	79	270	81
35,000	260	30							260	75	280	82	280	65	300	76	260	102	270	79
40,000	270	49									280	74	270	94	310	101	250	148	240	50
45,000	270	62									290	80					270	142		
50,000	280	64									280	118					260	153		
55,000	270	158																		
Maximum height (ft.)	57,370		33,445		28,809		20,773		39,237		51,826		40,210		40,210		52,902		40,210	
Maximum speed (kt.) Height (ft.)	159 55,150		96 30,200		88 27,200		97 20,773		103 39,237		128 51,826		94 40,210		101 40,210		171 46,695		88 38,049	
How lost	Low elevation		Low elevation		Low elevation		Low elevation		Low elevation		Low elevation		Low elevation		In haze		Low elevation		Behind Cu	

before the September hurricane reached its nearest point to Nassau when it was impossible to follow a 100-gm. balloon higher than 9,000 ft. because of thick haze, there being little cloud present.

Sheets of cirrus, base 30,000–35,000 ft., present a greater difficulty in summer, being present almost daily, due to the cumulonimbus clouds over larger islands in the vicinity.

Between October 1946 and December 1947 there were 55 cases of ascents up to or above 35,000 ft., 27 cases of ascents up to or above 50,000 ft., and 5 cases of ascents up to or above 70,000 ft. The record ascent at Nassau was made on February 13, 1948, when a theoretical height of 79,280 ft. was reached.

In the table given for the ascents made at Piarco, it is to be noticed that there are no wind speeds greater than 35 kt. Because of the prevailing strong westerly upper current over Nassau in the winter months, winds far in excess of this figure have been measured on a number of occasions. Between October 1946 and December 1947 there were 32 cases of recorded winds equal to or greater than 50 kt. The highest wind speed recorded during this period was 171 kt. on November 5, 1947, at a height of 46,695 ft. The table opposite gives a selection of the ascents in which wind speeds of over 100 m.p.h. were recorded.

The best time of year for high-altitude ascents is during the winter months, particularly when an anticyclone is centred some 300–500 miles to the north or north-west. Unfortunately, few high-altitude ascents are possible when they are most needed during the approach of a hurricane in the summer months.

A. BEYNON

Nassau, Bahamas, March 18, 1948.

Formation of rain

It is now 15 years since Bergeron* suggested that the chief factor effecting the release of real precipitation, i.e. of precipitation of substantial intensity and containing moderate or large drops, is the difference in vapour pressure between ice and supercooled water. Neither Bergeron nor Findeisen—with whose name the theory is also associated—claimed that ice crystals are always necessary for the formation of rain. Bergeron in fact specified two other processes which might cause raindrops to form, viz. coalescence of droplets due to very intense electric fields and temperature differences between neighbouring cloud elements due to radiation effects. The contention of those who support the theory is that most substantial rainfalls are initiated by the co-existence of ice crystals and supercooled water drops.

Although a considerable amount of evidence can be adduced in favour of the theory it seems unlikely that we shall ever be able to obtain conclusive proof that it is correct. On the other hand one would think that if the theory were wrong it would not be difficult to accumulate evidence of numbers of occasions when substantial rainfall has occurred while the cloud tops were at a temperature well above the freezing point with no other clouds above them.

I have frequently heard it suggested that " it is well known that rain occurs in the tropics with the clouds wholly at temperatures above 0°C." but a search through the literature indicates that meteorologists who possess well documented

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*BERGERON, T.; On the physics of cloud and precipitation. *P. V. Met. Un. geod., géophys. int., Lisbon,* 1933, p. 156.

evidence of this type must be very averse to publishing it. In fact I have found only two well substantiated reports of substantial rain with the cloud tops above 0°C. (viz. Heywood* and Kotsch†). It is of interest that both these rainfalls were from layer-type clouds.

It would be of considerable interest if meteorologists who are able to do so would forward to the Editor reports of substantial rain on occasions when aircraft observations indicated with certainty that the cloud tops were at temperatures above 0°C.

A. C. BEST

NOTES AND NEWS

The first telegraphic daily weather report

The date, August 31, 1948, marks an important anniversary in the history of weather science, namely the centenary of weather reporting by telegraphy. The following is a reproduction of a table which appeared in the *Daily News* on August 31, 1848:—

STATE OF THE WIND AND WEATHER

(The state of the weather for the next two months must have such important consequences that we have made arrangements with the Electric Telegraph Company for a daily report.)

AT NINE O'CLOCK YESTERDAY MORNING the wind and weather at the under-mentioned places were as follows:—

Chelmsford	W.	Fine	Manchester	SE.	Cloudy
Colchester	WSW.	Fine	Masborough	W.	Fine
Derby	NE. by N.	Fine	Newcastle	SSW.	Fine
Gloucester	ESE.	Fine	Newmarket	W.	Fine
Glasgow	SW.	Fine	Norwich	W.	Very fine
Gosport	WNW.	Fine	Normanton	SW. by S.	Very fine
Hertford	N.	Fine	Nottingham	W.	Fine
Hull	WSW.	Fine	Peterborough	NE.	Fine
Leeds	W.	Fine	Poole	W.	Fine
Leicester	W.	Fine	Portsmouth	WNW.	Fine
Leith	W.	Fine	Rugby	S.	Very fine
Lincoln	S.	Fine	Southampton	NW.	Fine
Liverpool	NW.	Fine	Yarmouth	W.	Fine
London	W.	Fine	York	NW.	Fine
Lowestoft	W.	Cloudy			

This brief report, giving only the wind direction and the weather at 29 places in England, was the modest beginning of the whole complex organization for weather reporting on which the modern science of forecasting depends. It was the first time in history that anyone had been able to obtain reasonably prompt information as to the weather conditions existing over a large area at the same hour. The collection of synchronous weather reports in this way led naturally to the construction of charts on which the space distribution of weather elements could be studied. The recognition of definite weather systems, and of the fact that changes of weather were mostly associated with the movement of such systems, inevitably followed and scientific weather forecasting thus became a possibility.

The telegraphic weather reports appeared daily in the *Daily News* until October 30, 1848, and were then suspended. They had been very much

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*HEYWOOD, G. S. P.; Rain formation in the tropics. *Quart. J. R. met. Soc., London,* **66**, 1940, p. 46.

†KOTSCH, W. J.; An example of colloidal instability of clouds in tropical latitudes. *Bull. Amer. met. Soc., Lancaster Pa.,* **28**, 1947, p. 87.

RUBBER-DINGHY ROWING FROM THE *Weather Recorder*, APRIL 1948

[*To face page* 232

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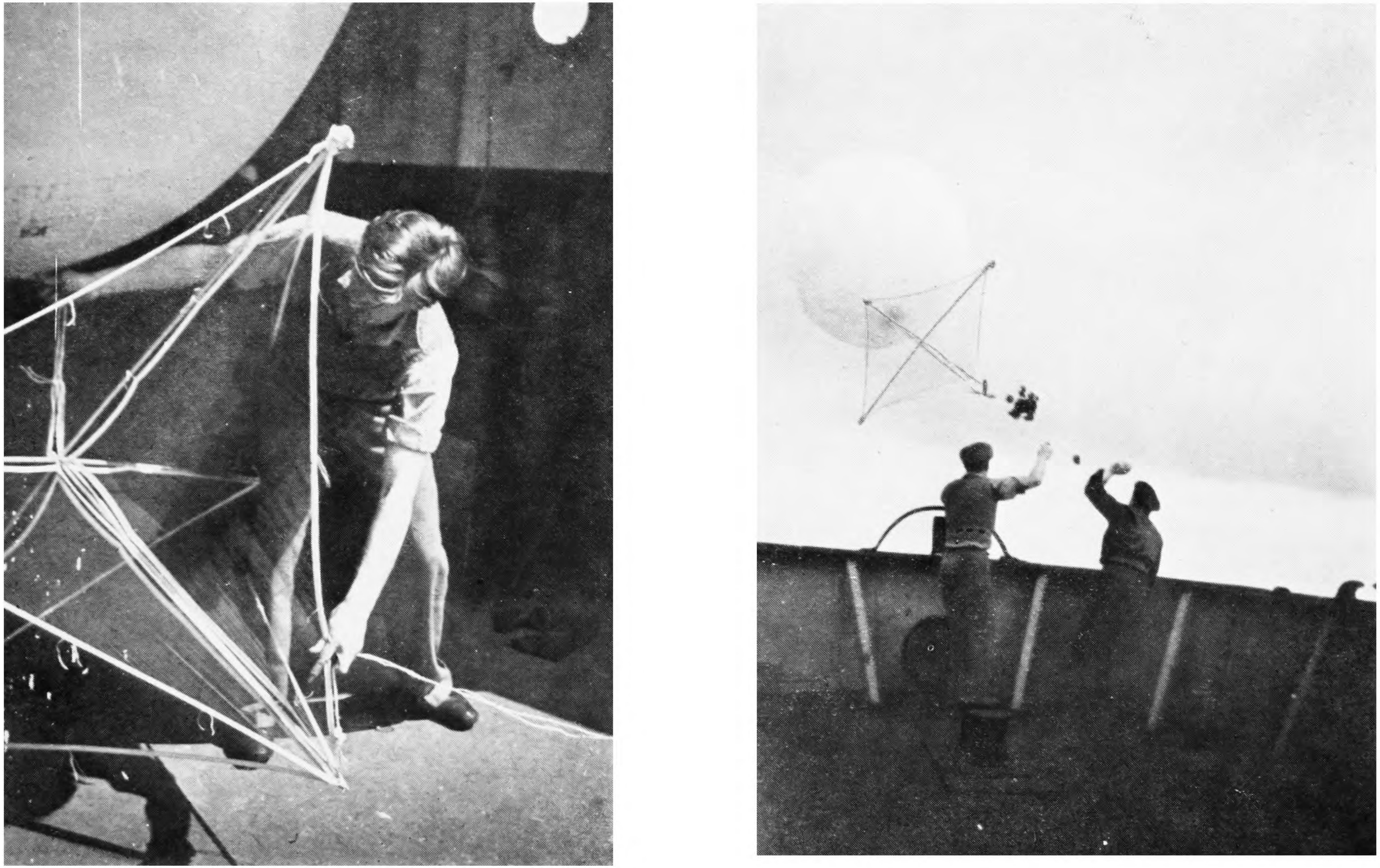

ASSEMBLING AND LAUNCHING A RADIO-SONDE BALLOON FROM AN OCEAN WEATHER SHIP appreciated and there was a considerable public demand for their resumption. Among those who pressed for their reappearance was the Astronomer Royal, and in a leading article published on March 17, 1849, the newspaper made the welcome announcement that arrangements had been made with the co-operation of the Astronomer Royal and certain railway companies to resume the reports on a new and improved basis. The technical supervision of the scheme was entrusted to James Glaisher, Superintendent of the Magnetic and Meteorological Department at Greenwich Observatory, and it was planned to include reports from over fifty stations. Under Glaisher's enthusiastic direction, the reports were made accurately and promptly from well selected sites, and synoptic meteorology—to use the modern term—was thus set going in Great Britain.

Glaisher was one of the most distinguished figures in meteorology during the Victorian era. Born in 1809, he joined the staff of Greenwich Observatory in 1835 and became Superintendent of the Magnetic and Meteorological Department on its creation in 1840. Among many original contributions to meteorology special mention must be made of his " Hygrometrical Tables ", published in 1847, which were for many years the standard tables for the computation of humidity from readings of dry- and wet-bulb thermometers. During the years 1862–6 he made a large number of balloon ascents with the aeronaut Henry Coxwell to study the meteorology of the upper air. The most famous of these ascents was made from Wolverhampton on September 5, 1862, when the great altitude of about 7 miles was reached. Glaisher became insensible at 29,000 ft., and Coxwell's hands became so frozen that he was only able to open the valve by seizing the cord with his teeth and dipping his head.

The public spirit and lofty scientific ideals which inspired the proprietors of the *Daily News* in their pioneer effort of a hundred years ago are eloquently expressed in the leader of March 17, 1849:—

" It is scarcely necessary to point out the scientific importance of such reports. Though much has been done of late years to throw light upon the theory of the laws which regulate storms and atmospheric phenomena in general, much remains to be done. . . . The results of the knowledge which must thus be acquired will possess a high practical utility as well as philosophical interest, for it is impossible to conjecture beforehand the extent to which navigation, horticulture, agriculture, and even mechanical processes of manufacture, may be benefited by juster views and more extended knowledge of meteorological science."

E. G. BILHAM

Old meteorological prints

Mr. C. E. Britton is well known for his researches into historical references to the weather which occur in early literature. As a counterpart to these studies Mr. Britton has made a collection of old documents and prints of a meteorological character and has generously presented them to the Meteorological Office. Eight of the most interesting have been framed and now decorate the walls of the Conference Room in Victory House.

Six of the pictures are old prints depicting the Thames frozen over during the severe winters of 1683, 1739–40, 1789 and 1814. The first of these is the winter which is described so vividly in " Lorna Doone ". On the second and fourth dates mentioned we see the frozen river covered with the booths and other paraphernalia which constituted the " Frost Fairs ". Some of the prints bear statements which show that they were actually printed on the ice. St. Paul's Cathedral and the Monument are conspicuous features on some of the pictures; but it is interesting to see in 1683 the Old London Bridge with its houses, whilst the later prints show the London Bridge as we know it.

In a pair of frames are to be seen two Royal Proclamations of King Charles I. The first, dated January 8, 1661, commands a " General and Public Fast to be kept throughout this whole Kingdom ", and exhorts the people to prayers for less severe weather. The second Proclamation, dated June 7 of the same year, refers to the " great and immoderate Rains and Waters that have lately faln in the Land " and commands the observance of a similar " religous exercise ".

Visitors to Victory House should make a point of seeing these very interesting pictures and documents which the generosity and zeal of Mr. Britton have placed in our possession.

N. K. JOHNSON

Seventy-five years of rainfall recording

The death on January 19, 1948, of Mr. John D. Walker of Ruddington, near Nottingham, at the age of 91, removes from the ranks of rainfall observers an enthusiast who broke all previous records by maintaining continuous observations over no less than three-quarters of a century.

Mr. Walker personally wrote out his rainfall return for 1947 and sent it to the Meteorological Office at Harrow less than a fortnight before his death. In a letter—written in a remarkably bold hand for a nonagenarian—he expressed his satisfaction in completing 75 years of daily recording in the Nottingham district but was fearful that owing to infirmities consequent upon age the observations might have to be discontinued. Mr. Walker sent his records to the British Rainfall Organization from 1873 to 1919, and to the Meteorological Office from 1920 onwards so that the 75 years' observations are preserved for posterity. The series is not strictly homogeneous as Mr. Walker changed his address three times during this long period.

So far as is known only three other observers have recorded meteorological observations for so much as 70 years. These were the Mackinnon of Mackinnon, who kept a rainfall record for 70 years at his seat Drumduan, near Forres, Morayshire, Sir John Eldon Bankes who observed at Soughton Hall in Flintshire, also for 70 years, and Sir John Moore who made observations in Dublin over a period of 73 years.

The late Mr. Walker was advised of these contemporary cases in a letter of congratulation regarding which his son writes:—

" My father was delighted and very proud to receive your letter and to know that he had created a record. He received the letter just after he was taken ill with what proved to be his last illness, but he showed me the letter with pride and remarked that he had never before been in such distinguished company. His rainfall record was a hobby of which he never tired. Even in his last days it kept cropping up in conversation. It is my intention to carry on the record if I can. I bear his exact name so we will see what we can do between us."

It is of interest to note that these four outstanding cases of notably long records were kept by an Englishman, a Scotsman, a Welshman and an Irishman, so that it may truly be said that honours are even.

H. E. CARTER

BOOKS RECEIVED

Jaarboek B. Aardmagnetisme (*Yearbook B. Geomagnetism*) 1945. Koninklijk Nederlands Meteorologisch Instituut, No. 98. Size: 13½ in. × 9½ in., pp. v + 26. 's-Gravenhage. Price 1·55 *florins*.

Summary of the meteorological observations made at the meteorological stations in the Netherlands West Indies during the year 1939, compiled by the Netherlands Meteorological Institute. Size: 9½ in. × 6¾ in., pp. 8. 's-Gravenhage. Price 0·20 *florins*.

REVIEWS

La Foudre, by Charles Maurain. Collection Armand Col~~l~~in, No. 248, 8vo, 1948, 7 in. × 5 in., pp. 215, *Illus*. Continental Publishers Ltd., London. Price 4*s*. 0*d*.

The author of this little book is Honorary Professor of Geophysics at the University of Paris. The book covers a wider field than its title suggests, for it is essentially a review of the present state of knowledge of the electricity of disturbed weather. The author, in his preface, states this to be the object of the book and presumably he adopted the title " La Foudre ", which means the " thunderbolt " as well as lightning, so as to make a more popular appeal.

The book starts with a couple of chapters on the general electrical properties of the atmosphere, both in quiet and disturbed weather, before introducing the more detailed account of the phenomena of thunderstorm electricity. Chapter III describes the various methods by which lightning has been studied and is followed by a good account of the main results. The structure of thunderclouds and the theories of generation of electricity in them are then discussed as well as the theories of the mechanism of the lightning discharge, including, of course, the important work of Schonland, Loeb and Meek. Some pages are devoted to the fundamental question of the maintenance of the earth's electric charge and there is also quite a good account of the work on atmospherics. A useful bibliography is included but very few illustrations are provided. There is a list of contents but an index would have been more useful.

There are one or two statements in the book which may not be readily accepted. For example on page 21 Professor Maurain distinguishes between heat thunderstorms and frontal thunderstorms and says that the former are the less violent. This might well be questioned unless the violence is measured by the frequency of lightning flashes to earth, for in heat storms these are relatively less frequent than in frontal storms. Again, on page 91, it is stated, quite correctly, that a field of 30,000 v./cm. is required to produce a spark in air at ordinary pressure but the author goes on to say that this value is attained at the place where a lightning discharge commences. Macky's experiments in 1931, however, showed that in a thundercloud the presence of small water drops, in addition to the lower pressure, makes the critical value of the field at which breakdown occurs of the order of 10,000 v./cm.

This book is rather similar in scope to Schonland's monograph on "Atmospheric Electricity " which was published 16 years ago. The subject has advanced considerably since then and there was a need for a more up-to-date survey. Professor Maurain has provided a very readable and comprehensive account of the subject and has, indeed, done exceedingly well to compress so much detailed information into such a small volume. Owing, evidently, to the poor exchange of scientific information during and just after the war he has, apart from a footnote or two added at the proof stage, not included any work more recent than 1943. There is, for example, no mention of Chalmer's work on various problems of thunderstorm electricity, of Frenkel's adsorption theory of the electrification of water drops and ice particles or of the work on lightning currents by Stekolnikov and by Bruce and Golde. Neither is there any mention of the possibilities of radar as a means of investigating thunderstorms, but it would be asking rather a lot to expect such a small book to cover as recent a development as this. However, despite these omissions, which will only be missed by the specialists, the general reader will find this book presents a good and easily understandable survey of the main methods, results and theories of the electrical phenomena associated with stormy weather.

F. J. SCRASE

Le climat écologique de la cuvette centrale Congolaise, by Étienne Bernard. Publication de l'Institut National pour l'étude agronomique du Congo Belge, 8vo. 11¼ in. × 8¾ in., pp. 240. *Illus.* Marcel Hayez, Brussels, 1945, Price: 300 *fr.*

This book deals with the general ecological climate of the central Congo basin, which is defined as the land below 500 m. between the parallels of 4°N. and 4°S., and the meridians of 16° and 26°E. The whole of this region is covered with equatorial rain-forest and the climate is discussed from standard observations at a few widely scattered stations. However, the climate, which is best described as equatorial continental, is remarkably homogeneous, and it is therefore legitimate to generalise from few data.

A large part of the volume is devoted to a discussion of the usual climatic elements, including humidity and evaporation. Although the ecological significance of each element is emphasised, most of the text, tables and diagrams are of great value to anybody studying the climatology of the region. We learn, for example, that the diurnal variation of rainfall shows a principal maximum between midnight and dawn, and only a secondary maximum in the afternoon, a result which is based on observers' notes and which it would be interesting to have confirmed by autographic records.

One of the most interesting features of the book is a chapter on radiation. The author admits the paucity of his observations, but makes good use of the material at his disposal and presents many facts in a new light. To give but one example, he points out that life on the earth is possible only because atmospheric ozone absorbs all the strongly antibiotic ultra-violet rays of wave-length less than 0·28 μ.

There is a comprehensive bibliography at the end of the book which deals with both general, ecological and meteorological topics and also with the climatology of central Africa.

In the introduction to the volume it is mentioned that more detailed investigations are to be carried out. It is to be hoped that it will not be too long before the present stimulating publication is continued by a work dealing with the microclimates of the equatorial forest and its clearings.

W. H. HOGG

On the kinematic structure of transition layers between air masses, by P. Groen, *Meded. Verh. Ned. Inst., De Bilt*, Serie B., Deel 1, Nr. 6. 4to. 12½ in. × 9 in. pp. 8. Rijksuitgeverij/'s-Gravenhage, 1947. Price: 1 *florin.*

This short note by Dr. Groen analyses the structure of a frontal transition zone by eliminating ρ, the density, in favour of θ, the potential temperature of the air. By this means he derives an expression for the slope of a front and a relation between velocity parallel to the front and potential temperature. He also examines the effect of viscosity and evaluates what he calls the "anti-viscosity gradient", being the gradient necessary to counterbalance viscosity without leading to any motion of the front. It may amount to as much as 1 mb./1,000 Km.

Whilst this analysis is applicable to more general cases and the solution of the viscosity problem is very neat, so far as it goes, it still makes no allowance for the equally important vertical motion and the more important acceleration effects. With these limitations it provides a useful transformation of Margules' formula and extends it to most practical distributions of velocity and potential temperature.

P. B. SARSON

ERRATUM

September 1948, PAGE 205, paragraph 4.—Potato blight is caused by a fungus, not by a virus. Study of the microclimate of the potato field is important both for the insect-borne virus diseases such as "leaf roll" and the fungus diseases.

WEATHER OF AUGUST 1948

During the first two days of the month pressure was rather uniform and nearly normal over the British Isles. A ridge of relatively high pressure moved eastwards across the country on the 4th. Depressions soon advanced from the Atlantic, and there was no steady anticyclonic period until after the 26th. The most notable depression was centred near Brest on the evening of the 7th, when pressure was as low as 969 mb. at its centre; it moved north-eastwards across south-east England during the night of the 7th and forenoon of the 8th. A shallower disturbance moved north-eastwards across central England during the 11th and the early hours of the 12th, while a third crossed southern Scotland in the early hours of the 16th. A quieter period followed, until a rapidly deepening depression approached the south-west coast of Ireland during the night of the 20th, turning northwards on the 21st and then eastwards along the sixtieth parallel to reach southern Norway on the evening of the 24th. Yet another deep depression moved east-north-east across southern Scotland on the afternoon of the 25th. This was followed by an anticyclone which covered the British Isles on the 27th and 28th, its north-west flank remaining over south-east England to the end of the month.

The map of mean pressure for the month shows the usual anticyclone over the Azores, with pressure above 1020 mb., and mean pressure about 1015 mb. over most of the eastern part of the U.S.A., central and southern Europe, and the Mediterranean. A region with mean pressure slightly below 1010 mb. extended from the north-west of Russia across Scandinavia and Scotland at least as far as longitude 20°W. Pressure was one or two millibars below the normal over most of Europe, and not far from normal over the eastern part of the U.S.A., and around Iceland and the Azores.

The weather over the British Isles was unsettled, dull and wet, with heavy rain storms causing severe floods in some areas.

The warm weather experienced at the end of July continued over August 1, the thunderstorm area shifting north. On the 2nd a shallow trough of low pressure stretching from Denmark to France extended its influence over England giving widespread thunderstorms associated with heavy local rain; 3·94 in. was measured at Silsoe, Bedfordshire, 3·44 in. at Cranham, Gloucestershire, and 3·02 in. at Bridgend, Glamorgan. Meanwhile a current of polar air moved south over Scotland and temperature fell, first in the north and by the 3rd over the whole country. From the 4th to the 6th troughs of low pressure moved north-east over England giving rain in most areas except the north of Scotland. On the 7th a vigorous secondary depression approached south-west England and subsequently moved north-east across southern England to the south of Norway. Gales occurred in the English Channel and along the south coast on the night of the 7th–8th and considerable rain fell except in the north of Scotland. On the 10th a shallow depression moved south-east to the Bristol Channel and later turned north-east across England to the southern North Sea. Heavy thundery rains occurred in the Midlands and north-east England on the 11th and in Northumberland and the Border counties on the 12th causing heavy damage and flooding in those areas (Kelso, Roxburgh, had 6·21 in. and Belford, Northumberland, 4·35 in.). At Kelso the river Tweed rose 6½ in. higher than in the previous highest flood of 1831. On the 15th and 16th another disturbance moved slowly east across the north of Ireland and south Scotland; further appreciable rain occurred in the north but there was little or none in the south. From the 21st to the 24th a depression off south-west Ireland moved north to southward of Iceland and then east across the north of Scotland to southern Scandinavia where it filled. There were local gales in the west and north and further rain. On the 23rd a shallow secondary moved east-north-east along the English Channel. On the 25th a new deep depression west of Scotland moved rather quickly east-north-east and was associated with local gales on its southern side and appreciable rainfall in the north and west. In the rear of this disturbance a ridge of high pressure moved in from the west over the British Isles and intensified. Later it continued moving east to the North Sea and mainly fair weather persisted over England until the 31st. On the 28th and 29th a trough moving east over our north-west districts gave further rain in the north and west. On the last day a trough of low pressure moved east over the country giving general rain, heavy in the west.

The general character of the weather is shown by the following table:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days' difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	83	37	−0·9	134	+1	73	28
Scotland	78	29	−1·1	159	0	64	18
Northern Ireland..	73	38	−0·2	96	+3	74	22

RAINFALL OF AUGUST 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	3·02	137	*Glam.*	Cardiff, Penylan ..	5·65	134
Kent	Folkestone, Cherry Gdns.	3·52	147	*Pemb.*	St. Ann's Head ..	3·79	114
,,	Edenbridge, Falconhurst	5·23	200	*Card.*	Aberystwyth	6·15	160
Sussex	Compton, Compton Ho.	4·79	155	*Radnor*	Bir. W. W., Tyrmynydd	4·94	92
,,	Worthing, Beach Ho.Pk.	3·99	177	*Mont.*	Lake Vyrnwy	7·31	142
Hants	Ventnor, Roy. Nat. Hos.	3·99	201	*Mer.*	Blaenau Festiniog ..	12·78	114
,,	Bournemouth	3·44	137	*Carn.*	Llandudno	2·72	97
,,	Sherborne St. John ..	4·27	176	*Angl.*	Llanerchymedd ..	3·48	96
Herts.	Royston, Therfield Rec.	4·13	161	*I. Man.*	Douglas, Boro' Cem. ..	5·72	150
Bucks.	Slough, Upton	2·76	127	*Wigtown*	Port William, Monreith	3·52	91
Oxford	Oxford, Radcliffe ..	3·43	150	*Dumf.*	Dumfries, Crichton R.I.	7·63	189
N'hant.	Wellingboro', Swanspool	2·31	97	,,	Eskdalemuir Obsy. ..	10·00	194
Essex	Shoeburyness	2·89	163	*Roxb.*	Kelso, Floors	10·46	355
Suffolk	Campsea Ashe, High Ho.	3·18	161	*Peebles*	Stobo Castle	7·21	203
,,	Lowestoft Sec. School ..	2·90	132	*Berwick*	Marchmont House ..	9·57	289
,,	Bury St. Ed., Westley H.	4·10	158	*E. Loth.*	North Berwick Res. ..	8·02	254
Norfolk	Sandringham Ho. Gdns.	2·60	96	*Midl'n.*	Edinburgh, Blackf'd. H.	9·40	293
Wilts.	Bishops Cannings ..	2·93	95	*Lanark*	Hamilton W. W., T'nhill	6·09	178
Dorset	Creech Grange.. ..	3·90	136	*Ayr*	Colmonell, Knockdolian	3·53	88
,,	Beaminster, East St. ..	5·53	177	,,	Glen Afton, Ayr San ..	7·23	134
Devon	Teignmouth, Den Gdns.	2·72	120	*Bute*	Rothesay, Ardencraig	7·71	158
,,	Cullompton	3·92	129	*Argyll*	L. Sunart, Glenborrodale	5·95	105
,,	Barnstaple, N. Dev. Ath.	4·05	123	,,	Poltalloch	3·44	70
,,	Okehampton, Uplands	3·90	92	,,	Inverary Castle	9·75	148
Cornwall	Bude School House ..	3·16	112	,,	Islay, Eallabus ..	5·62	129
,,	Penzance, Morrab Gdns.	3·96	125	,,	Tiree	3·96	94
,,	St. Austell, Trevarna ..	3·65	101	*Kinross*	Loch Leven Sluice ..	8·06	210
,,	Scilly, Tresco Abbey ..	3·11	113	*Fife*	Leuchars Airfield ..	5·67	184
Glos.	Cirencester	3·56	119	*Perth*	Loch Dhu	11·45	170
Salop.	Church Stretton ..	3·07	92	,,	Crieff, Strathearn Hyd.	7·56	180
,,	Cheswardine Hall ..	3·90	117	,,	Blair Castle Gardens ..	..	..
Staffs.	Leek, Wall Grange P.S.	4·51	124	*Angus*	Montrose, Sunnyside ..	5·50	197
Worcs.	Malvern, Free Library	4·75	164	*Aberd.*	Balmoral Castle Gdns...	5·73	189
Warwick	Birmingham, Edgbaston	4·39	162	,,	Dyce, Craibstone ..	4·52	149
Leics.	Thornton Reservoir ..	3·95	141	,,	Fyvie Castle	5·18	163
Lincs.	Boston, Skirbeck ..	3·68	154	*Moray*	Gordon Castle	7·04	222
,,	Skegness, Marine Gdns.	4·41	181	*Nairn*	Nairn, Achareidh ..	4·77	196
Notts.	Mansfield, Carr Bank ..	3·40	122	*Inv's*	Loch Ness, Foyers ..	8·63	282
Ches.	Bidston Observatory ..	2·36	77	,,	Glenquoich	7·90	96
Lancs.	Manchester, Whit. Park	4·00	116	,,	Fort William, Teviot ..	8·51	137
,,	Stonyhurst College ..	4·68	92	,,	Skye, Duntuilm ..	5·55	125
,,	Blackpool	3·66	102	*R. & C.*	Ullapool	3·32	97
Yorks.	Wakefield, Clarence Pk.	3·73	143	,,	Applecross Gardens ..	6·08	129
,,	Hull, Pearson Park ..	3·47	119	,,	Achnashellach	6·08	96
,,	Felixkirk, Mt. St. John	3·19	112	,,	Stornoway Airfield ..	3·79	101
,,	York Museum	3·77	150	*Suth.*	Lairg	3·71	117
,,	Scarborough	2·61	94	,,	Loch More, Achfary ..	5·58	96
,,	Middlesbrough.. ..	3·63	132	*Caith.*	Wick Airfield	2·94	107
,,	Baldersdale, Hury Res.	4·20	120	*Shet.*	Lerwick Observatory ..	2·17	72
Norl'd.	Newcastle, Leazes Pk. ..	4·65	165	*Ferm.*	Crom Castle	4·11	99
,,	Bellingham, High Green	5·66	160	*Armagh*	Armagh Observatory ..	3·50	97
,,	Lilburn Tower Gdns. ..	7·84	278	*Down*	Seaforde	4·50	120
Cumb.	Geltsdale	6·14	149	*Antrim*	Aldergrove Airfield ..	2·89	80
,,	Keswick, High Hill ..	6·62	127	,,	Ballymena, Harryville..	3·31	78
,,	Ravenglass, The Grove	3·94	86	*Lon.*	Garvagh, Moneydig ..	3·85	98
Mon.	Abergavenny Larchfield	4·79	161	,,	Londonderry, Creggan	4·72	102
Glam.	Ystalyfera, Wern House	9·39	152	*Tyrone*	Omagh, Edenfel ..	4·02	94

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, APRIL 1948

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
	Mean of day M.S.L.	Diff. from normal	Absolute		Mean values											
			Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily Mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1012·8	−0·6	69	36	58·3	42·3	50·3	+3·2	46·2	69	5·8	1·24	−0·21	13	7·1	52
Gibraltar	1013·5	−2·9	74	51	68·5	56·1	62·3	+1·4	57·3	75	5·3	2·78	—	14	8·0	61
Malta	1013·8	+0·4	75	46	66·0	53·5	59·7	−1·2	57·4	72	5·3	0·76	—	6	9·5	73
St. Helena	1015·0	−0·4	74	59	71·0	61·7	66·3	+1·6	61·2	92	8·9	3·25	−0·22	17	—	—
Freetown, Sierra Leone	1010·6	+1·4	94	73	85·3	77·3	81·3	+0·1	75·7	78	5·6	2·32	−1·74	7	6·8	55
Lagos, Nigeria ..	1009·9	+0·5	94	66	89·5	71·3	80·4	−2·4	77·8	81	8·8	4·12	—	11	5·1	42
Kaduna, Nigeria ..	1007·6	—	97	64	91·5	71·0	81·3	−0·9	72·7	70	7·5	5·92	+2·84	7	7·4	60
Chileka, Nyasaland	1015·9	−0·3	86	60	80·9	64·4	72·7	+0·9	67·9	75	5·3	3·03	+1·63	8	6·8	58
Lusaka, Rhodesia ..	1013·3	−0·2	84	56	78·8	60·1	69·5	+0·6	63·9	78	5·9	0·72	−0·04	5	7·1	61
Salisbury, Rhodesia	1015·3	−0·2	81	52	76·0	56·6	66·3	+0·4	60·5	78	5·0	2·27	+1·20	6	7·2	61
Cape Town	1016·8	+0·4	103	46	74·4	55·6	65·0	+1·8	55·2	75	4·7	1·91	+0·04	12	—	—
Germiston, South Africa	1016·1	—	78	37	70·5	49·5	60·0	—	51·1	68	2·2	3·12	—	6	9·2	80
Mauritius	1013·9	0·0	88	66	82·9	71·4	77·1	+1·3	72·5	82	5·7	10·40	+5·28	21	6·8	59
Calcutta, Alipore Obsy.	1005·1	−0·3	99	71	95·2	77·5	86·3	+0·7	77·8	80	4·5	0·73	−1·45	5	9·7	77
Bombay	1008·2	−0·6	94	75	90·9	77·8	84·3	+1·2	76·7	77	2·8	0·00	−0·05	0	9·8	78
Madras	1008·3	−0·1	99	72	95·0	78·3	86·7	+1·4	77·8	75	5·1	0·44	−0·19	1	9·9	80
Colombo, Ceylon ..	1009·7	+1·0	90	72	87·8	75·4	81·6	−1·1	76·2	89	7·0	11·39	+1·66	20	7·8	63
Singapore	1009·0	+0·1	93	71	90·2	75·5	82·9	+1·3	77·6	81	5·7	4·26	−3·37	10	—	—
Hongkong	1012·5	−0·1	84	64	77·6	68·5	73·1	+2·3	69·3	86	—	6·07	+0·42	19	2·9	23
Sydney, N.S.W. ..	1017·6	−0·8	81	47	70·1	56·7	63·4	−1·3	57·3	72	5·0	1·38	−4·11	12	6·2	55
Melbourne	1018·9	−0·6	85	40	66·5	51·4	58·9	−0·6	53·0	71	7·6	3·37	+1·20	16	4·0	36
Adelaide	1020·8	+1·0	90	49	70·2	54·6	62·4	−1·5	55·4	63	7·7	4·66	+2·94	13	5·1	46
Perth, W. Australia	1017·7	−0·7	82	49	74·3	56·5	65·4	−1·4	57·9	57	4·0	2·19	+0·54	13	7·4	66
Coolgardie	1019·4	+1·1	84	41	71·0	52·1	61·5	−3·5	52·9	60	3·8	0·78	−0·18	5	—	—
Brisbane	1016·6	−1·0	87	52	76·8	59·9	68·3	−2·0	60·9	63	4·9	4·15	+0·38	12	7·2	63
Hobart, Tasmania	1018·4	+3·6	79	41	60·8	47·2	54·0	−1·2	49·5	74	7·7	2·27	+0·42	17	4·0	37
Wellington, N.Z. ..																
Suva, Fiji	1010·4	−0·2	86	68	83·4	72·5	77·9	−0·7	75·0	86	6·1	18·34	+6·13	17	6·7	57
Apia, Samoa ..	1010·1	+0·4	89	72	87·0	74·7	80·9	+0·7	77·5	80	7·3	12·34	+2·57	22	5·8	49
Kingston, Jamaica	1014·3	+0·2	91	67	88·0	71·4	79·7	+1·3	73·9	73	3·6	0·61	−0·63	5	9·7	78
Grenada, W. Indies	1013·3	+0·8	87	66	85·0	74·6	79·8	+0·9	74·7	75	7·5	0·65	−1·51	9	—	—
Toronto	1018·4	+2·3	71	25	54·8	38·0	46·4	+4·3	38·7	67	6·8	1·96	−0·33	11	5·9	44
Winnipeg	1015·1	−1·6	70	−5	43·7	26·8	35·3	−2·4	27·7	—	6·7	2·13	+0·73	12	5·9	43
St. John, N.B. ..	1017·4	+4·0	54	20	44·6	30·8	37·7	−1·3	33·3	78	6·4	4·50	+0·99	18	5·3	39
Victoria, B.C. .	1013·0	−4·5	61	27	52·9	38·8	45·9	−2·0	39·2	90	6·7	1·55	+0·03	15	5·9	43

M.O. 501 AIR MINISTRY

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METEOROLOGICAL RESEARCH FLIGHT

BY RONALD FRITH, M.A., Ph.D.

From the time, a century or two ago, of the earliest meteorological measurements in the free air, our knowledge of conditions in the troposphere and lower stratosphere has increased, at varying rates, through observations obtained from manned balloons, kites, sounding balloons, pilot balloons and, within about the last 30 years, aircraft and radio-sondes. Before 1939, the number of routine soundings enabled upper air pressure and temperature charts to be prepared regularly for certain areas. The years of war saw a greatly increased use of radio-sondes for determination of temperature and humidity to heights in excess of normal aircraft ceiling, and the introduction and extended use of radio and radar methods for wind measurements.

Nevertheless the information obtained, whether from aircraft or radio-sonde, was far from complete. For example, humidity measurements, except at comparatively high temperatures, were either lacking or inaccurate. The presence of cloud, and its type, could be reported from an aircraft, but no measurements could be made of its density (liquid or solid content) or the number and size of its particles.

It was believed that knowledge of these quantities would not only benefit the general science of meteorology, but would be of great value in connexion with two special problems thrown into prominence by the war—icing and condensation trails.

So, in 1942, it was arranged that the High Altitude Flight at Boscombe Down should give facilities for meteorological investigations to be carried out by meteorologists in aircraft. The initial objective was the improvement of existing aircraft meteorological instruments and the development of new ones. It was expected that in the course of this work the research unit would accumulate valuable meteorological data. This expectation has been justified.

Early work.—*Temperature measurements* made from aircraft require correction for the speed of the aircraft. With fast, high-flying aircraft this correction is very large (in excess of 20°F.). It had been realised for some time that existing determinations of the " speed correction coefficient " were not sufficiently accurate, so one of the first tasks imposed on this new unit was to measure these coefficients and to assist the Instruments Division of the Meteorological Office in the design and development of new thermometers.

Many types of thermometer were tested and eventually a completely new, distant-reading, electrical instrument was developed. This, the flat-plate electrical thermometer, is rapid in response and very accurate. It is suitable for all types of aircraft, including single-seater single-engined types, and is now widely used.

Humidity measurements.—Rapid progress was also made by Dr. G. M. B. Dobson of Oxford University in association with Mr. A. W. Brewer, the Meteorological Officer of the flying research unit, in the development of an aircraft frost-point hygrometer.

At this time there were two standard ways of measuring the humidity in the upper air—(i) the wet- and dry-bulb psychrometer; (ii) hygrometers using some substance responsive to changes in humidity (hair, goldbeater's skin, etc.). Both of these, satisfactory enough at moderate or high absolute humidities, fail completely at low absolute humidities. It was hoped that a frost-point hygrometer would work down to the lowest humidities likely to be found within the range of present-day aircraft. This proved to be the case, and on December 22, 1943, the new instrument was used on an ascent which penetrated the stratosphere. Fig. 1 shows the results of this sounding. These are believed to be the first reliable measurements of humidity ever made in the stratosphere.

Since then some 50 similar ascents have been made.

At low levels too, the instrument gave information of great interest. Frost points as low as −50°F. and relative humidities of less than 1 per cent. were found to be not uncommon in subsided air.

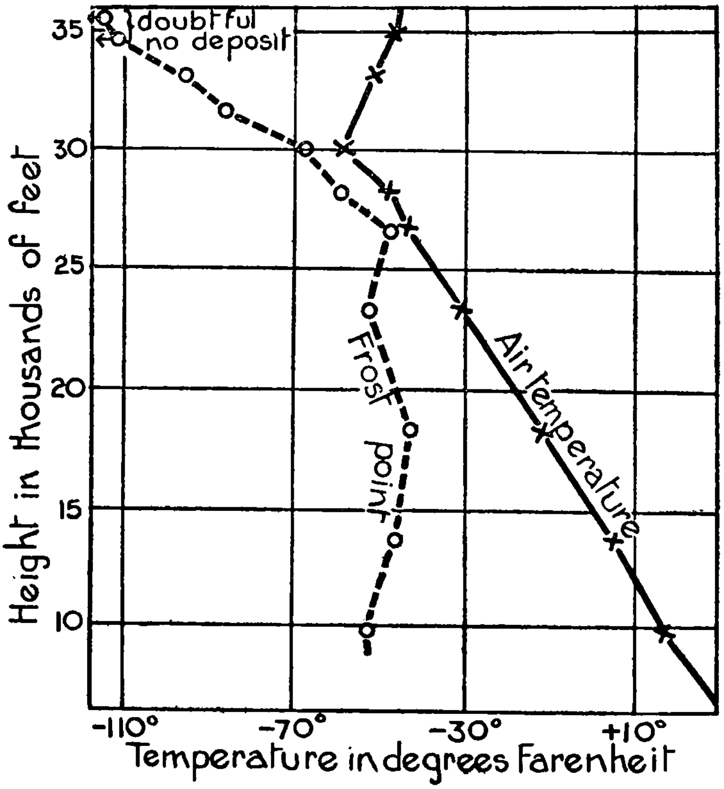

FIG. 1—THE FIRST ASCENT WHEN HUMIDITIES WERE MEASURED IN THE STRATOSPHERE
Boscombe Down, December 22, 1943

In 1946 the research unit was transferred to the Royal Aircraft Establishment at South Farnborough, re-equipped with two Halifax and two Mosquito aircraft, and renamed the Meteorological Research Flight.

Meteorological Research Flight.—Although the flight is still very much concerned with the development of aircraft meteorological instruments, a regular part of the work now consists in the use of instruments previously developed, either here or elsewhere, for the study of the atmosphere.

High-level and high-speed work.—About 10 ascents into the stratosphere, using Mosquito aircraft, are aimed at each month. The ascents generally reach 39,000 or 40,000 ft. and take about 1¼ hr.

Especially since the installation of remote-controlled frost-point hygrometers, in which the frost is " seen " photo-electrically, these trips (if nothing goes wrong) can be quite pleasant.

It is also planned to use these aircraft to assist in the development of totally different methods of measuring humidity at very high levels.

Apart from this humidity work, Mosquito aircraft are also used to check the air-temperature speed corrections at high speeds, and at high levels. This work is tiring. It entails flying, generally at 30,000 ft., to and fro, in the same air as near as can be determined, and at various speeds. A complete run consists of eight legs, on each of which the aircraft is flown steadily for a minute or two at each of the following speeds: 220, 240...360 m.p.h. Such a run takes about 2½ hr. But so variable are the air temperatures that the means of the eight readings obtained at each speed still do not lie smoothly on a curve; and a great many similar runs are required before a firm value for the speed correction coefficient can be found.

Medium- and low-level work.—The Halifax aircraft are used for work up to 20,000 ft. This consists mainly of:—

(*a*) A study of the " fine " structure of the atmosphere. This work is of importance, for example, in connexion with turbulence and generally atmospheric stability.

(*b*) A study of the structure of clouds and of the development of rain.

For some time work under (*a*) consisted mainly of detailed readings of temperature and humidity during a slow ascent or descent. These readings appeared to show that " subsidence inversions " were very common, and very complex. However it has been lately realised that variations in the horizontal also are often quite large, and special attention is now being given to mapping temperature and humidity over horizontal areas, generally of about 30 mi. × 20 mi. Fig. 2 shows such a map.

It takes 2–2½ hr. to make a survey of this size and requires at least three observers—one to operate the frost-point hygrometer, one to operate the electrical thermometer and the third to take readings of airspeed, height, position, etc. If possible, a fourth observer makes independent temperature readings.

A number of these surveys have now been made under widely differing synoptic situations. Broadly speaking they show temperature and humidity patterns, generally closed, on a scale measured in tens of miles, with a temperature range of about 1°F. and a frost-point range of 10–20°F. or even more.

The frost-point and temperature isopleths are generally similar, dry air being warm, and moist air cold.

Item (*b*), the study of the structure of clouds and of the development of rain, is perhaps the most interesting of all our work. It is certainly the most difficult. It involves:—

(i) The measurement of the numbers and sizes of cloud particles and of rain drops.

(ii) The recognition of ice crystals as distinct from water droplets in a cloud.

(iii) The study of where and how rain develops.

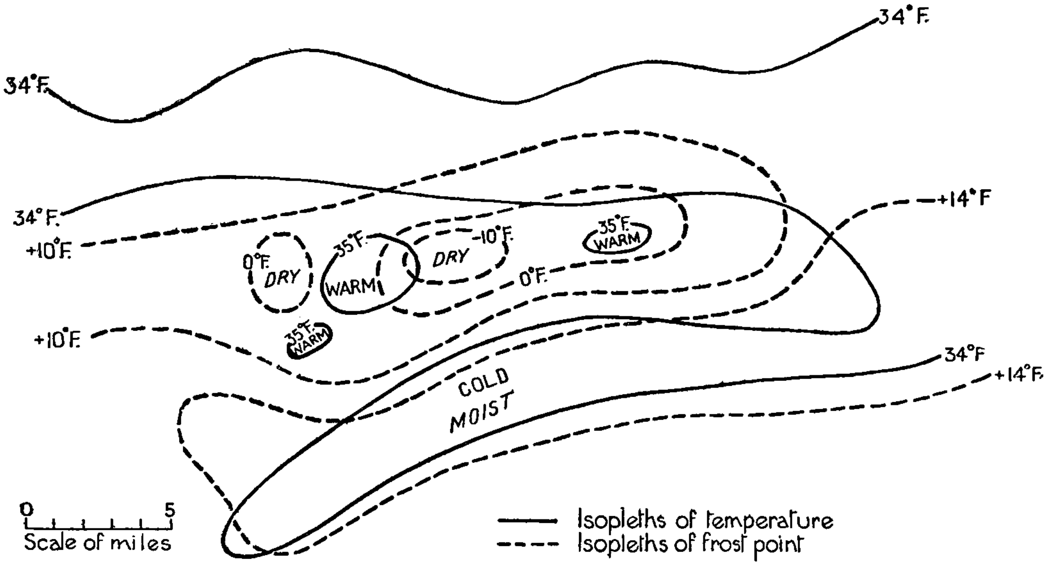

FIG. 2—ISOPLETHS OF FROST POINT AND TEMPERATURE AT 10,000 FT. OVER SOUTH MIDLANDS, APRIL 27, 1948

At present qualitative measurements are obtained of the sizes and the numbers of cloud particles by exposing in the cloud for a short period (1/100 sec.) a microscope slide in a suitably designed container. The slide is coated with soot, magnesium oxide or a green gelatine film. Using any of these coatings each cloud particle which strikes the slide leaves a pit or stain. By examining the slide under a microscope, counting and measuring the pits or stains, a qualitative picture of the size distribution is obtained and thus of the water content in the cloud. Figs. 3 and 4 (facing p. 252) show a typical slide magnified 100 times and work in progress in the aircraft.

Ice crystals leave an irregular pit on the soot- or magnesium-oxide-coated slides and can thus be recognised.

Other instruments are in course of development which will make similar measurements either photographically or, in supercooled clouds, by measuring the rate of ice formation on rods of different diameters.

Work is also progressing, in co-operation with the Instruments Division of the Meteorological Office, on apparatus, suitable for use in aircraft, for measuring the sizes of drizzle and rain drops.

The formation of rain is studied in two ways; first, by making ascents through warm-front cloud systems, and observing visually and instrumentally all that is to be observed, and secondly, by studying the development of cumulus clouds as they grow into shower clouds.

The study of the development of cumulus clouds has presented a quite unforeseen difficulty in the rapidity with which these clouds grow and decay, so that a promising-looking cloud, by the time one has reached it, is either a fully developed cumulonimbus, or else has practically disappeared. In this way one can fly about from cloud to cloud for hours without ever being present when a cumulus cloud begins to precipitate.

Ground work.—In the preceding sections stress has largely been laid on work in the air. On the ground there is, on the one hand, a good deal of work to be done in measuring and counting, in computing and tabulating; and, on the other, there are always past results to study, to write up and, if possible, to explain.

For the instrument-development work the flight has its own workshop, and employs an instrument maker.

So, whether it is a " flying day " or not, there is always plenty of interesting work to be done, and, perchance, new discoveries to be made.

CALCULATION OF THE RELATIVE HUMIDITY WHEN THE AIR TEMPERATURE IS BELOW 32°F.

BY R. H. COLLINGBOURNE, M.SC.

The relative humidity, U, is defined* by the relation $U = 100\, r/r_w$ where r is the mixing ratio of the air and r_w is the saturation mixing ratio at the same temperature and pressure. This is, however, for most practical purposes, equivalent to

$$U = 100\, e'/e'_w$$

where e' is the vapour pressure of the air and e'_w is the saturation vapour pressure at the temperature of the air T. When, however, the air temperature is below 32°F. the saturation vapour pressure has two possible values, the saturation vapour pressure over ice and the saturation vapour pressure over supercooled water. There are therefore two values of the relative humidity under these conditions and a convention has to be adopted as to which is used. The present Meteorological Office practice is to calculate the relative humidity with reference to saturation over ice, but it is proposed that, after January 1, 1949, in accordance with a resolution passed by the Conference of Directors in 1947, the relative humidity shall be calculated with reference to saturation over liquid water at all temperatures. The revised definition will give lower values of the relative humidity at temperatures below 32°F. It is the purpose of this note to show what changes will be necessary in the present method of using the Bilham humidity slide-rule to calculate the relative humidity.

The humidity slide-rule, designed by E. G. Bilham†, is used at most Meteorological Office stations. The instrument, at present in use, is designated the Mk. II and differs in a number of points from that originally described by Bilham, which is now called the Mk. I. In the Mk. II (illustrated facing p. 253), scale 4, on the upper edge of the slide, is a scale of temperature such that the distance of any graduation mark, T, from a certain fixed point is equal to the value of $\log e'_w$ on the same scale as the logarithmic scale 5 on the top of the stock. The point marked with an arrow and the letters R.H. is the value of T for which e'_w is equal to 100 mb. The usual operation for calculating the relative humidity is thus equivalent to finding the value of $100\ e'/e'_w$ by normal slide-rule methods. At temperatures below 32°F. the values of e'_w used in graduating scale 4 correspond to saturation over ice and incorrect values of the relative humidity, on the new definition, will therefore be obtained in these conditions.

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*I.M.O. Conference of Directors, Washington, D.C., Resolution 166, 1947.

†BILHAM, E. G.; A slide-rule for hygrometric calculations. *Met. Mag., London*, **70**, 1935, p. 254.

In these cases it is, however, possible to find an " adjusted " dry-bulb temperature such that the saturation vapour pressure over ice at this temperature is equal to the saturation vapour pressure over supercooled water at the true dry-bulb temperature. If this adjusted dry-bulb temperature is then used in the normal way in place of the true dry-bulb temperature the correct value of the relative humidity will be obtained. This adjusted temperature can be found by putting the cursor over the value of the true dry-bulb temperature on scale 1a and reading the adjusted dry-bulb temperature on scale 1 (the saturation vapour pressure over supercooled water at the true dry-bulb temperature is given by the reading of the cursor on scale 2 and this also equals the saturation vapour pressure over ice at the reading of the cursor on scale 1). The adjusted dry-bulb temperature is always greater than the true dry-bulb temperature.

The procedure can be summarised as follows:—

(*a*) Find the vapour pressure e' in the normal way (note that scale 3a should be used in place of scale 3, or scale 3c in place of scale 3b if an Assmann psychrometer is being used).

(*b*) Place the cursor over the value of the dry-bulb temperature on scale 1a and read off the adjusted dry-bulb temperature on scale 1.

(*c*) Use in the normal way the value of e' already found and the adjusted dry-bulb temperature to find the relative humidity.

The values of e'_w at temperatures below 32°F. which were used in graduating scale 4 on the original Mk. I instrument correspond to saturation over supercooled water (i.e. this instrument would give the correct values of the relative humidity at all temperatures without the necessity of computing an adjusted temperature). A new model of the humidity slide-rule will be produced in the near future which will have scale 4 altered to correspond with that on the original Mk. I.

PHENOMENAL RAINFALL AT SEMMERING, AUSTRIA

BY A. H. GORDON, M.S. (Pasadena)

On June 5, 1947, between 1340 and 2045 local summer time the phenomenal precipitation of over 12 in. was recorded by the official Austrian meteorological reporting station at Semmering, near the existing boundary between the British and Soviet zones of occupation. The accuracy of this figure as an exact measure of the precipitation fallen is perhaps open to some doubt, because of the extraordinary circumstances prevailing. However, in view of the observations made during the storm and the damage which occurred there is little question but that a fall of excessive and " cloud-burst " proportions did occur.

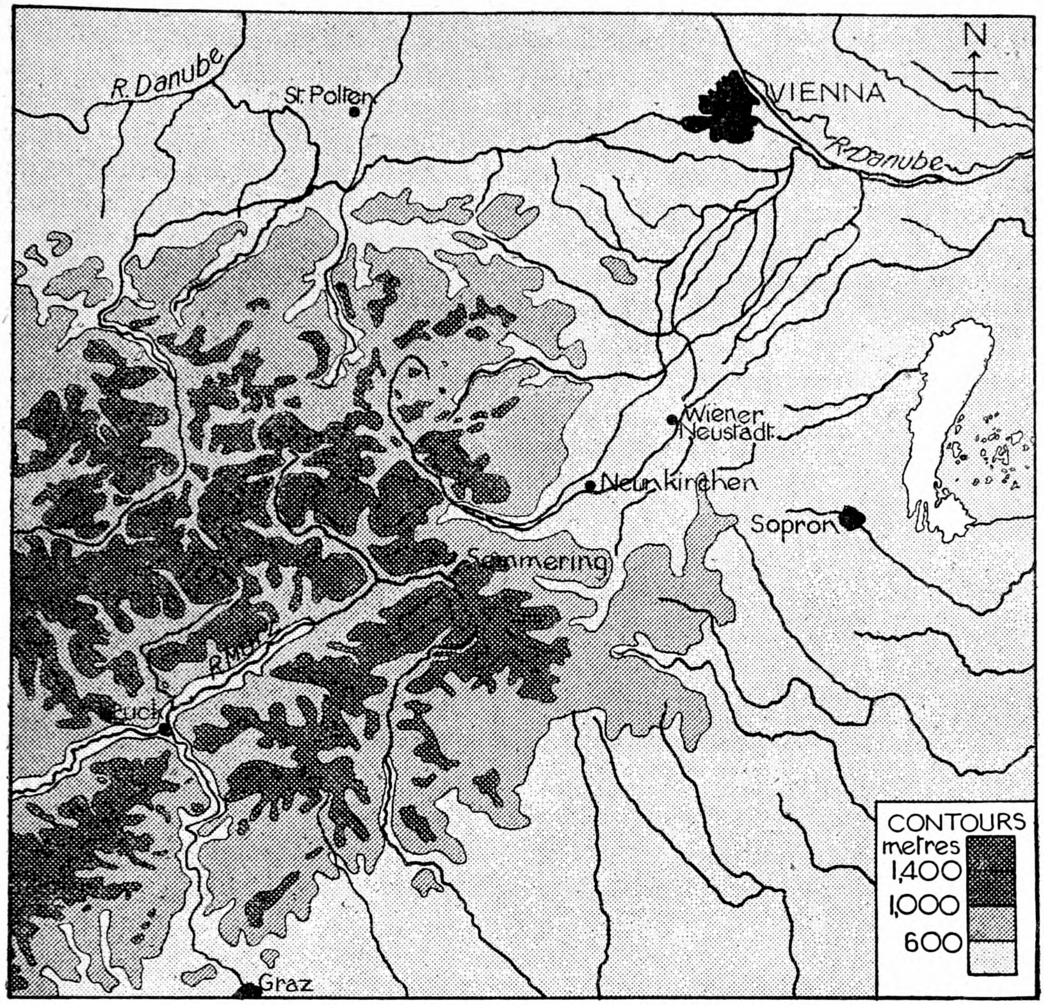

FIG. 1—MAP OF THE AREA ROUND SEMMERING

The actual descriptive report from the observer at the Semmering station, as translated from the German and condensed, is as follows:—

On June 5, 1947, a violent thunderstorm, accompanied by a " cloud-burst " hailstorm began at 1340 and lasted until 1545. The hailstones were on the average the size of small cherries. At 1430 the funnel of the rain-gauge was already filled with hailstones to within a hand's width of its edge, congesting the outlet; so we took off the funnel, removed the can and put the hailstones into the gauge. From 1545 until 1600 there was a slight pause during which there was only heavy rain. The thunder and hail recommenced at 1600 and lasted until 1645. This time the hailstones reached the size of large cherries, weighing 4·3 gm. From 1750 to 1830 there was more thunder and hail, the hailstones reaching the size of cherry stones. The hailstorm was unusually heavy. It rained uninterruptedly from 1340 to 2045. From 1845 to 2030 and from 2105 to 2145 thunder was heard and lightning seen. The ground was partially covered with hail 20 cm. deep. The district gave one the impression of a winter landscape.

To measure this extraordinary amount of rain, at 1915 we emptied the gauge* into two large receptacles and carried the water indoors. The hailstones had by that time melted. We immediately re-erected the rain-gauge with funnel and collecting can. There was another 0·12 in. of rain until 2100. So as not to lose any water, we syphoned it into the official measure; and, to lessen the possibility of making a false count, emptied the measure into a glass cylinder which could hold about one litre of water. At the level corresponding to an amount of 20 mm. (0·79 in.), twice the content of the official measure, we fixed a paper mark and put the water into the cylinder which had been prepared in this way. The cylinder was filled 16 times which corresponds to a quantity of 320 mm. (12·6 in.). This work was done together by the observers, Frl. Emma Bittner and Herr Magister Krakowka; Frl. Lina Taschner was also a witness and took part in the measurement. As the quantity of rain was so extraordinarily large, we also made a notch in the side of the gauge at the level reached by the water so as to be able to check the quantity of water on a future occasion of heavy rainfall. On June 6 we again filled the gauge 32 times with water from the official measure to prove the accuracy of our measurements.

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*See p. 250 for description of rain-gauge.

Readings (station level) at the time of the catastrophe

	1200	1400	1500	1600	1800	2000
Barograph (mb.) ..	894·6	895·2	..	897·2	897·4	897·2
Hygrograph (%) ..	56	99	..	97	96	96
Thermograph (°F.) ..	70	67	48	57	52	51

At Semmering on June 6 at 0700 at a temperature of 49°F. hail could still be found in places.

For the accuracy of this report:

EMMA BITTNER M.R. KRAKOWKA, Schoolmaster

Meteorological Observers

LINA TASCHNER

Witness

Summary of the damage caused.—The damage caused by the swollen rivers and by water rushing down the mountain sides into the narrow valleys was very extensive.

Bridges with iron girders were swept away. A railway embankment was destroyed at Semmering station leaving 30 ft. of track hanging in the air. Many roads had their surfaces destroyed for long distances and were left piled with rocks in places to a height of 6 ft. At one point a river changed its course and now flows along a former road. A rock wall, 26 ft. long and nearly a yard thick, was moved 3 yd. by water pressure and broken up against the rocks. The crops were totally destroyed in many fields. One death was reported.

The synoptic chart (Fig. 2) at 1200 G.M.T. on June 5, 1947, shows the general weather conditions just about the time of the commencement of the storm. The pressure distribution before the 5th had been very flat for about four days resulting in extreme heat over the whole of western Europe including the British Isles. Temperatures up to 92°F. had been recorded in Vienna and in the valleys of Austria during the period. The very hot weather was ended by the cold front shown in Fig. 2. The intensity of the storm at Semmering was of very local character. Elsewhere the passage of the front was accompanied by only light showers.

In Fig. 3, which gives the 700-mb. contours for 0600 G.M.T., the cold front is seen to be quite well marked at that level. The temperature at Sonnblick,

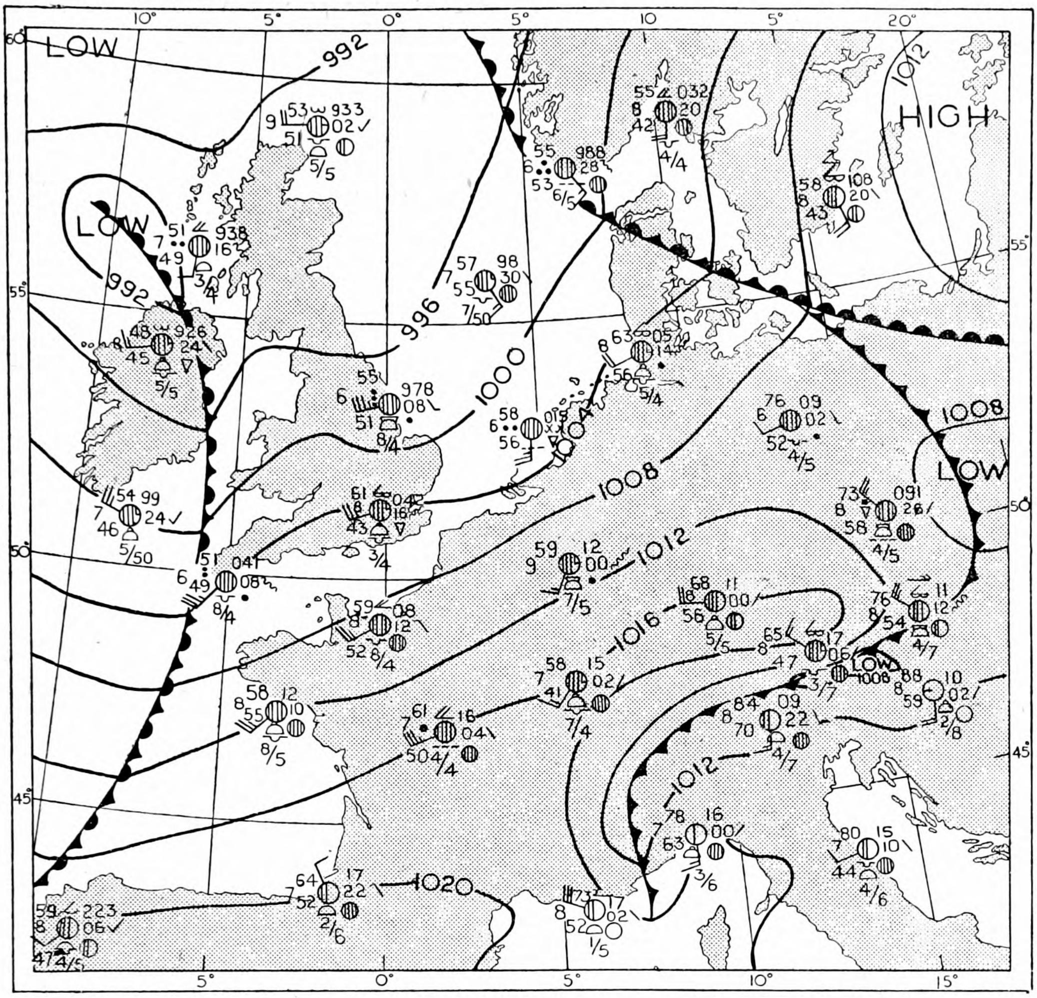
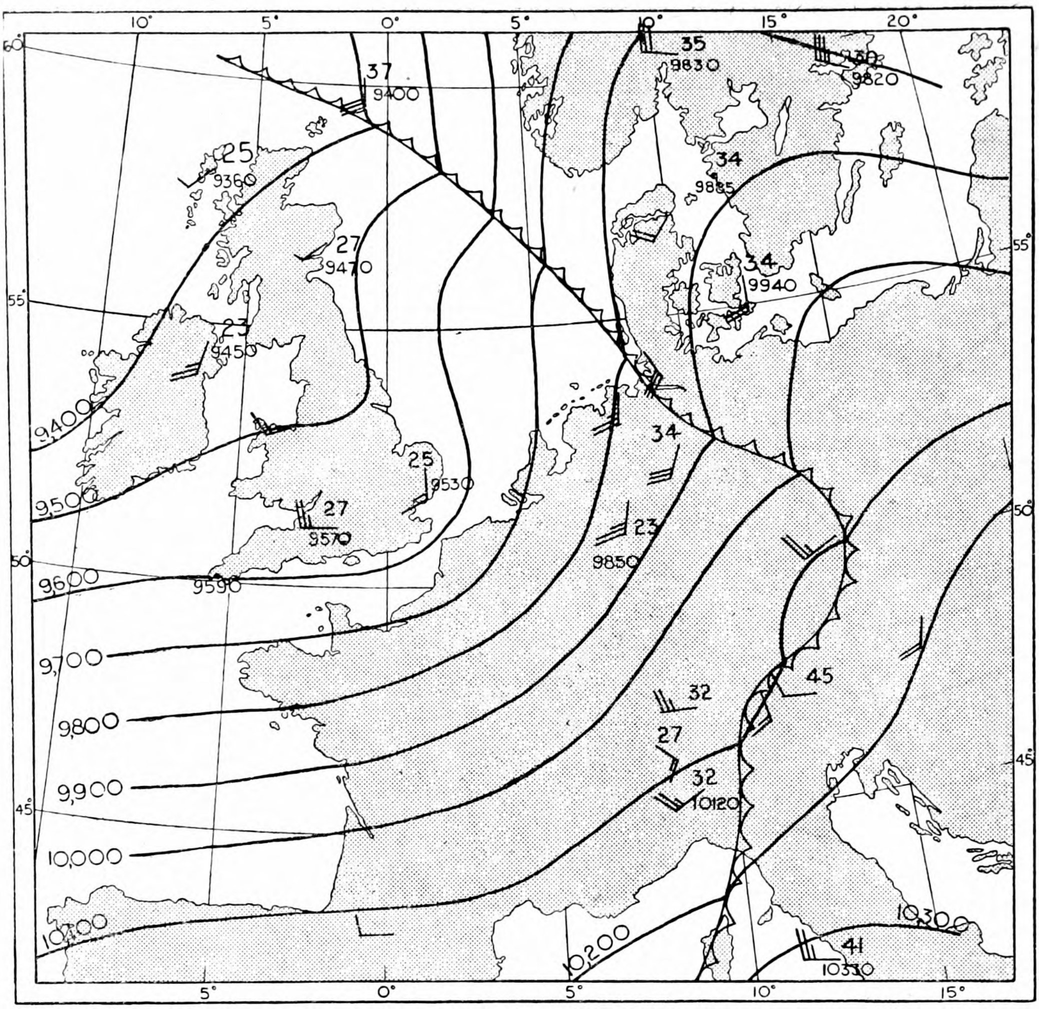


FIG. 2—SYNOPTIC CHART AT 1200 G.M.T., JUNE 5, 1947

approximately 10,000 ft. above sea level, is seen to be 45°F. At 1200 G.M.T it had dropped to 34°F. after the passage of the front.

The exact conditions responsible for the formation of a very moist and unstable pocket of air such as could produce such excessive precipitation are difficult to isolate and account for. Possibly such a pocket may have remained stagnant in a valley such as the Murztal for some days during the previous heat wave, continually drawing moisture from the numerous rivers and streams in the locality and from the rich verdant vegetation which prevails there. Such a pocket may have attained a high lapse rate, probably over 5°F./1000 ft. This, in itself, would not account for the unusual precipitation since such a lapse rate must have existed all along the cold front without causing anything exceptional. However, if the pocket had at the same time become very much moister than the surrounding air, it would have been capable of possessing the potential energy subsequently released. The arrival of the cold front, which may have driven the moist pocket north-eastwards up the Murz valley and over the high mountain slopes which surround the head of this valley, provided an external orographic effect sufficient to set this vast store of potential energy into violent action. The results have been ably shown already.

The formation of stagnant pockets of air in mountainous regions would

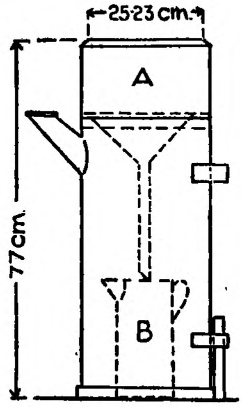


10°
5°
0°
5°
10°
15°
20°
60°
55°
50°
45°
37
9400
35
9830
30
9820
25
9360
34
9885
27
9470
34
9940
23
9450
9400
34
25
9530
9500
27
9570
23
9850
9600
9590
9700
45
32
9800
27
32
9900
10120
10,000
10,300
10,100
10,200
41
10330
5°
0°
5°
10°
15°

FIG. 3—CONTOURS OF 700-MB. SURFACE AT 0600 G.M.T., JUNE 5, 1947
The contours are drawn at 100-ft. intervals; the arrows fly with the wind, each feather being equivalent to 10 kt.

appear to dominate the local meteorology of these regions to a great extent and considerable investigation into this subject would appear to be needed.

[The type of rain-gauge used in Austria differs considerably from the British pattern. The Austrian one, 77 cm. high and 25·23 cm. in diameter, rests with its base on the ground and is held rigid by a wooden support. The diagram, copied from Kleinschmidt Fig. 1d, "Handbuch der meteorologischen Instrumente", p. 276, shows the construction.



25·23 cm.
A
77cm.
B

The heaviest rainfall in a thunderstorm recorded in the British Isles was 9·56 in. at Bruton, Somerset, on June 28, 1917. At Cannington, Somerset, on August 18, 1924, 8 in. fell in 5 hr. The heaviest fall in one day on the continent of Europe appears to have been 18·3 in. at Riposto, Sicily, on November 17, 1910.*

This fall of 12·6 in. at Semmering in 7 hr. is certainly among the heaviest ever recorded in Europe.—Ed. *M.M.*]

METEOROLOGICAL RESEARCH COMMITTEE

The third meeting of the Instruments Sub-Committee was held on September 9.

The Sub-Committee discussed alternative proposals for producing some form of radio equipment capable of measuring upper winds at a lower cost (both in terms of initial financial outlay and of financial and manpower maintenance costs) than that of the equipment in current use in this country. It was decided that radar equipment in some form is the most probable answer but a decision between two alternative ways of using radar principles was deferred until certain trials have been carried out.

An interim report on progress being made in the production of a high-powered searchlight for the exploration of the atmosphere at heights above the limit of radio-sondes was received. The progress made is very promising.

Discussion also took place on the accuracy of radio-sonde observations.

LETTERS TO THE EDITOR

Climatic change

At the end of his interesting article " Changes in the climate of London " in May 1948 issue of *Weather,* Mr. E. L. Hawke invites a possible explanation of the several changes which are revealed by his investigation.

May not the answer be that the mean position of the polar front in the northern hemisphere has gradually moved northwards? This might also explain apparent climatic changes during recent times in other parts of the northern hemisphere.

The effect of a general northward movement of the polar front and therefore of the mean track of depressions associated therewith would, I think, account for the conclusions reached by Mr. Hawke if one bears in mind that, in the northern hemisphere, the polar front has an annual movement southwards (in the winter) and northwards (in the summer) of its mean position throughout the year as a whole.

If in the seventeenth century polar air penetrated much farther southward than it does today, then one would expect generally colder weather and more summer frosts then than now. Moreover, in view of the well known instability of maritime polar air, especially when heated from below as happens durings its passage over warm land surfaces in summer, there could have been maximum rainfall in spring-summer and a greater frequency of hail in the seventeenth century. Nowadays, in summer, London would be more often under the influence of the relatively stable air which originates from the subtropical high, with the result that precipitation frequency would tend to reach a maximum in autumn-winter when the polar-front depressions are most active

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*BROOKS, C. E. P.; Abnormal rainfalls. *Met. Mag., London,* **62**, 1927, p. 1.

and effective. The more southerly track of depressions in the seventeenth century, causing unsettled weather and gales almost as often in the summer as in the winter, would also account for the greater movement of air and therefore fewer fogs which Mr. Hawke mentions as a feature of the period in question, 1669–89.

The reason for the northward drift of the frontogenetic zone of the polar front would, presumably, be some change in solar radiation resulting in a decrease of ice cover at the poles and a less extensive polar air mass—hence a diminishing and less vigorous southward movement of cold polar air ?

R. G. VERYARD

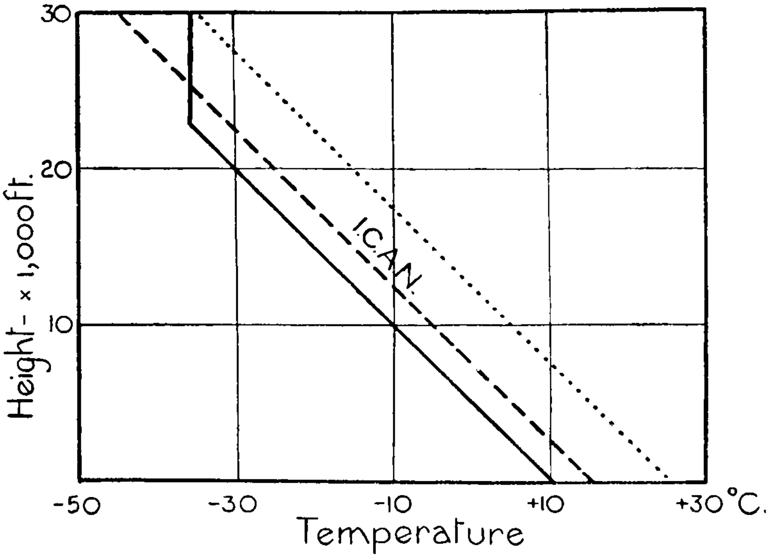
H.Q., R.A.F., Med./M.E., Ismalia, June 14, 1948

Notes on the I.C.A.N. altimeter and height and airspeed computor

In connexion with Mr. Bull's article " Notes on the I.C.A.N. altimeter and height and airspeed computor " in the issue of last February, it may be of interest to remark that use of the height and airspeed computor may sometimes appreciably *increase* the error of the altimeter.

This will occur, for example, when the aircraft is flying in the stratosphere, and the air temperature is higher than the standard I.C.A.N. temperature for that level. Tropopauses lower than 30,000 ft. are not infrequent, even in this country.

The figure makes this clear. The full line shows the actual air temperature, the pecked line shows the first approximation (I.C.A.N. atmosphere) and the dotted line shows the second approximation using the computor.



An example has been chosen almost at random. At Liverpool the 0000 G.M.T. ascent on October 24, 1944, showed a tropopause at 20,300 ft. The temperature at 30,000 ft. was −39°C. On an aircraft flying at a true height of 30,000 ft. the altimeter would indicate 30,660 ft. If the reading were " corrected " by means of a computor the result would be 31,500 ft., thus increasing the error from 660 ft. to 1,500 ft.

RONALD FRITH

Farnborough, Hampshire, May 24, 1948

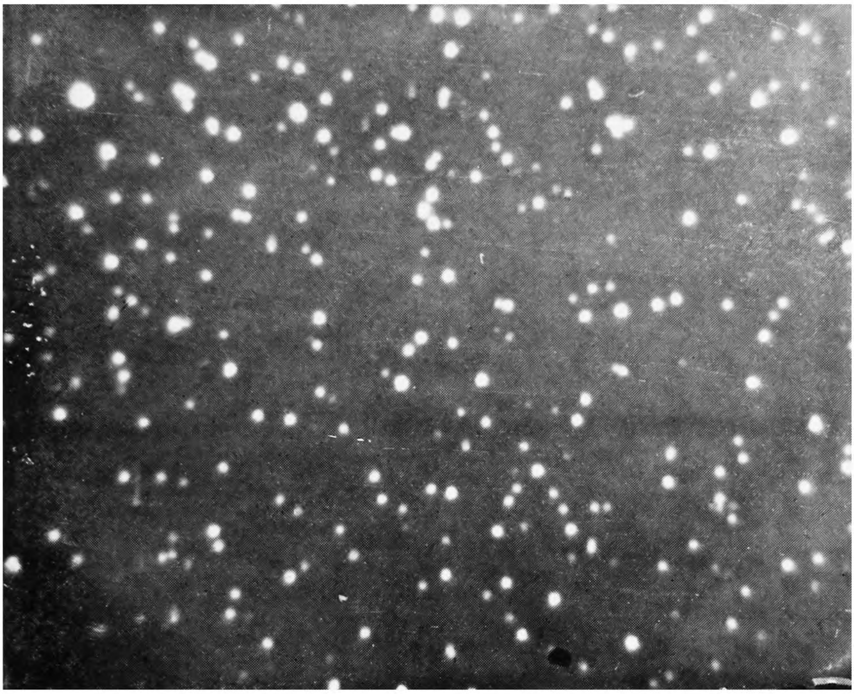


FIG. 3—CLOUD-PARTICLE PITS ON A MAGNESIUM-OXIDE SLIDE
(Magnification × 100)
Sample taken in stratocumulus at 2,000 ft., May 13. 1948

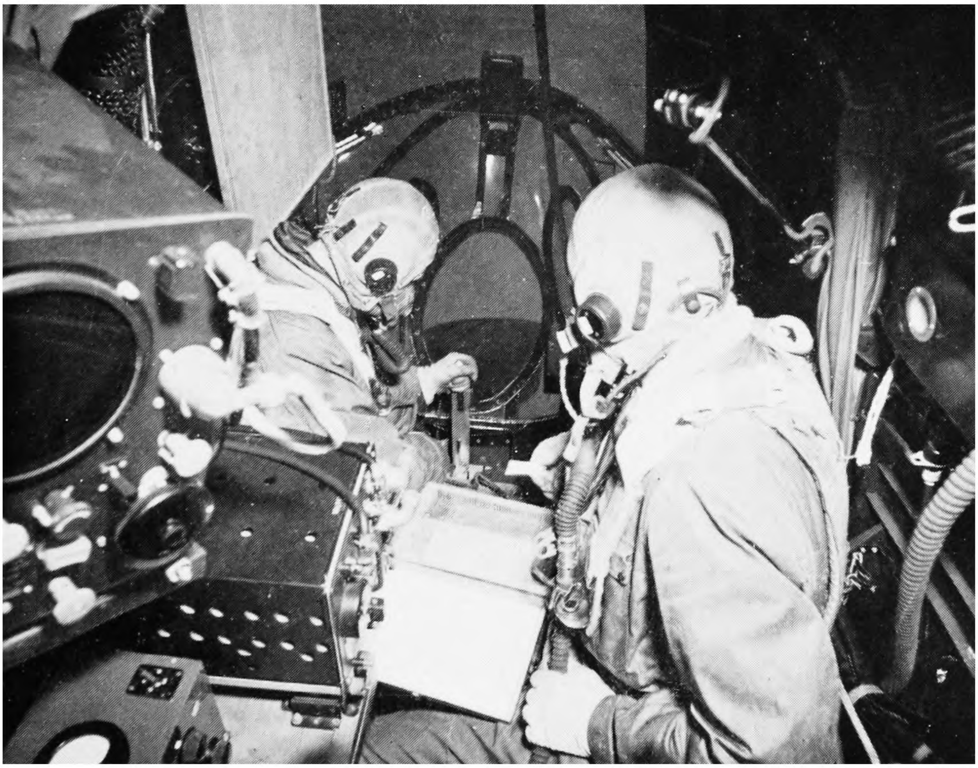
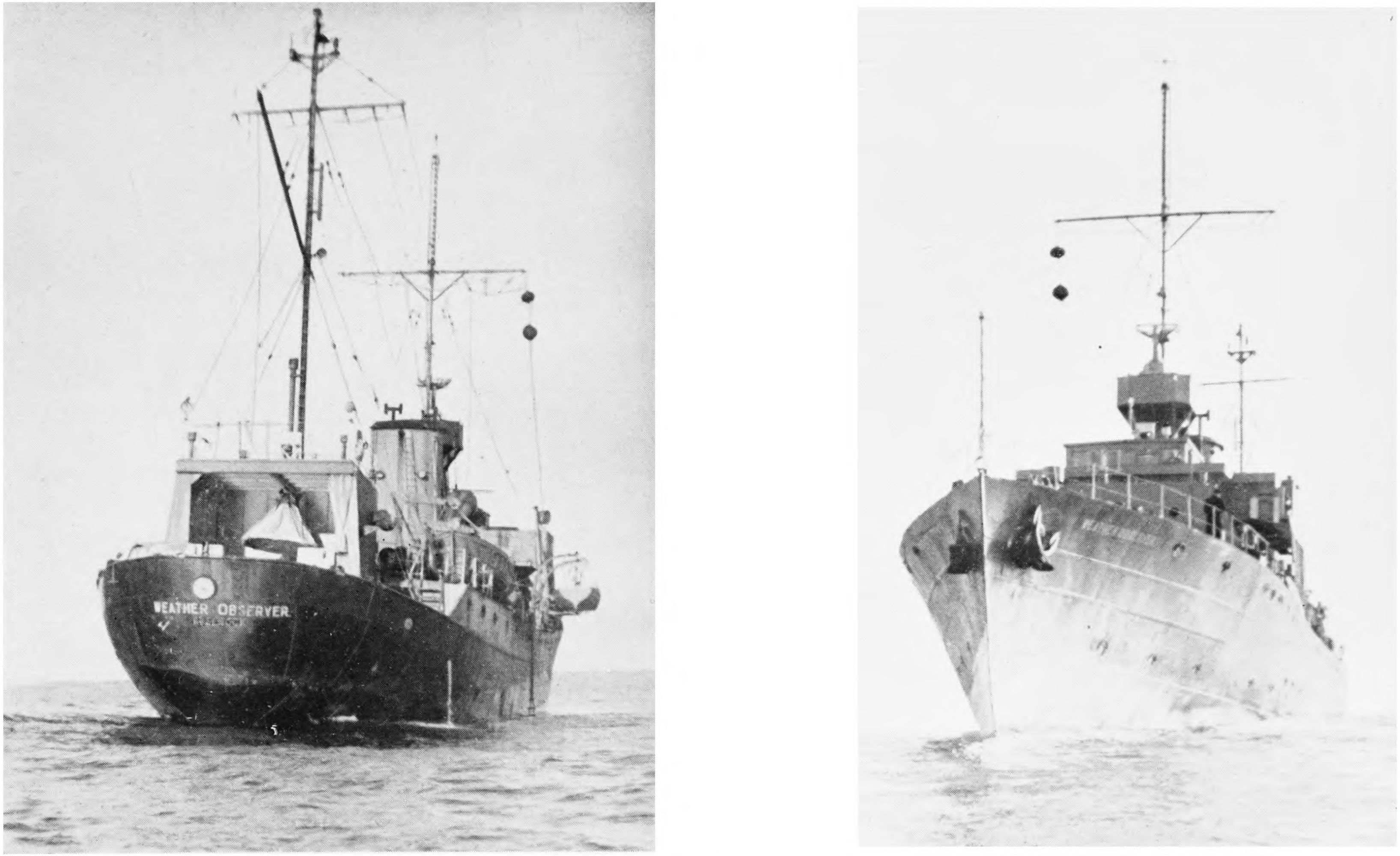


FIG. 4—MEASURING THE SIZE OF CLOUD PARTICLES FROM A HALIFAX
(see p. 244)

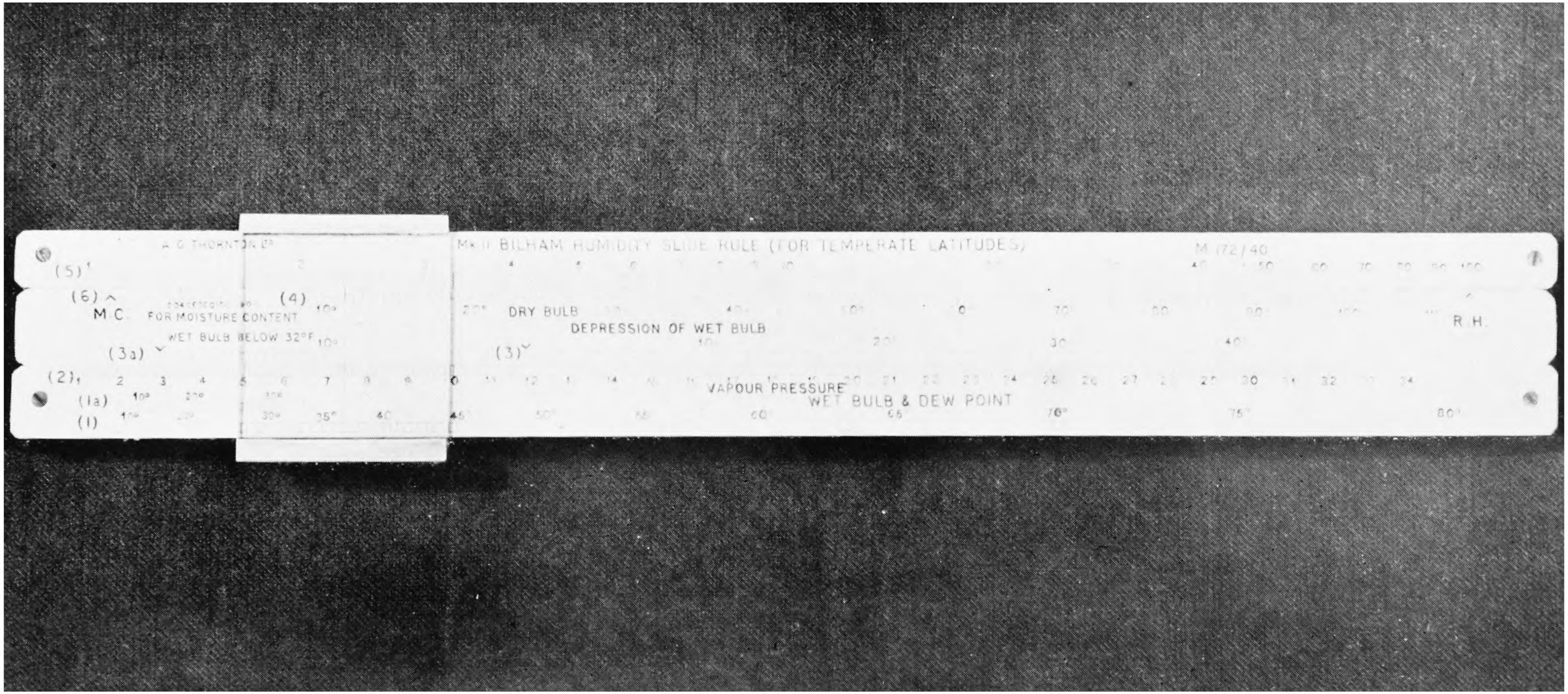
TWO AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT
(see p. 241)


WEATHER OBSERVER

O.W.S. *Weather Observer* UNDERGOING MINOR REPAIRS AT STATION JIG, APRIL 1948

The two black shapes at the foreyard indicate that the ship is unable to manoeuvre.

[*To face page* 253]


A. G. THORNTON L^D
Mk II BILHAM HUMIDITY SLIDE RULE (FOR TEMPERATE LATITUDES)
M 172/40
(5)
(6)
M.C.
FOR MOISTURE CONTENT
WET BULB BELOW 32°F
(4)
(3a)
(3)
DRY BULB
DEPRESSION OF WET BULB
R.H.
(2)
(1a)
(1)
VAPOUR PRESSURE
WET BULB & DEW POINT

BILHAM HUMIDITY SLIDE-RULE MK. II

(see p. 245)

Waterspouts and their danger to aircraft

During some work that I have recently been doing on the characteristics of waterspouts at sea, it occurred to me that these phenomena, which sometimes may be quite violent, might possibly account for the occasional inexplicable disappearance of aircraft at sea, particularly when that disappearance occurs at night in tropical and subtropical regions.

When an aircraft disappears without any form of earlier warning message or information being received that all is not well aboard, it would appear quite probable that the machine had come to a sudden, and in all probability a violent end. Such an end could quite reasonably be expected from collision in the dark with a waterspout column owing to its high rotational velocities.

The linear rotational velocities in a spout of only moderate intensity in temperate latitudes may reach the order of 100–200 kt., while those in the more violent tornado spouts, such as occur off the eastern seaboard of the United States, are believed to reach considerably higher. It is clear that the force behind such velocities would be capable of completely breaking up the strongest aircraft in a matter of a few seconds as a result of the huge strains inflicted on the component parts of the aircraft.

It is realised that a similar sort of occurrence could conceivably occur if an aircraft flies into the middle of a particularly violent cumulonimbus cloud in the dark. However, damage done to an aircraft by violent turbulence in a cumulonimbus cloud might not be as instantaneous as that done by an intense spout. It is possible that in the former case some warning of the danger that had been encountered might be sent out first. The height at which the aircraft is flying is an important factor since a damaging waterspout would normally be met below the cloud base. The captain of an aircraft might therefore consider that no bad weather danger existed if he was flying well below cumulonimbus cloud level. Neither need the waterspout column necessarily be met directly beneath the cumulonimbus cloud since the column frequently bends to a considerable distance away from the cloud from which it emerges. In daylight hours, the phenomenon of a waterspout would, of course, be seen and naturally avoided. At night, however, such would not necessarily be the case and there would be little warning of its existence in the aircraft's flight path. The spout would probably be too small to give a radar echo and thus give warning of its existence as in the case of a cumulonimbus cloud. Some danger might also arise through the shock of impact at a high speed with a mass of solid water although this would not be likely to occur unless the aircraft was flying very low. Although the waterspout column itself is composed of water droplets formed by condensation from dynamical reduction of pressure, evidence indicates that the more severe storm spouts carry considerable quantities of sea water up to a fair height. In the case of the famous Cottage City spout of 1896 the spray cascade itself rose to a height of 400 ft.

As to the forecasting of conditions suitable for the formation of waterspouts, in the light of present knowledge on the subject, a quotation from Willis Hurd of the U.S. Weather Bureau, who has done considerable work on these phenomena, is apt:—

" It has been shown that waterspouts spring into their brief existence under all manners and combinations of weather circumstances over warm water and cold water, though most frequently over warm. They are found to occur in weather settled and unsettled; in cyclones and in anticyclones; in calms, light winds, and gales; under all sky conditions from cloudless to overcast; in warm weather and in cold; at all seasons of the year. They are found to rotate in either sense, regardless of their low-pressure centers; to set their courses directly or at angles with or against the prevailing surface winds; to drop from the clouds and rise from the water; to exhibit moderate to terrific forces; to acquire many varieties of shapes and appearances from the ordinary to the grotesque, and to vary in size from small excrescences in the cloud, or mere whirls or protuberances on the water, to cloud-and-sea-spanning creations of monstrous diameter or length."

A. H. GORDON

Periodicities by least squares from sets of six observations daily

When we have a set of observational means u at each of a number of different times of day, there is something intriguing in the attempt to look for diurnal and semi-diurnal periods by threading them on to a curve of the type $u = a_0 + a_1 \sin(t + A_1) + a_2 \sin(2t + A_2)$. This can be done conveniently by the method of least squares, but the method has one serious drawback—it insists on giving a result.

It would be so much more obliging of it if it only gave results when there is a basis of physical reality behind them.

The fact that we get real values of a_1 a_2 A_1 A_2 in the equation above from six values of u (u_1, u_2, . . .) does not justify us in saying that there are periodic causes at work. It only justifies us in saying that if there are periodic causes at work, these are the most likely values for the connected constants. The answer to the " if " may be " yes " or " no ".

In a paper like Dr. Jameson's* the answer is unhesitatingly " yes ", as 864 cases are examined, there is close agreement throughout between observed and computed values, and a high degree of consistency in the values of a_0, a_1, a_2, A_1 and A_2. All this could not occur fortuitously.

However, other cases arise where the evidence is not so convincing, so that it is worth while to call attention to the simple criterion by which, with very little work, we can know how close the least-square sine curve will approach to the observational points from which it is built—which means, roughly, that before starting to build it, we can have a good idea whether it is worth while to do so.

If we deal with six observational means, at four-hourly intervals, per day (u_0, u_1, . . . u_5) it will be found that the sine curve by least squares goes equally near to each of them, alternately above and below.

If $u_0 = z_0 + a_0 + a_1 \sin(t + A_1) + a_2 \sin(2t + A_2)$ it will be found that $6z_0 = u_0 - u_1 + u_2 - u_3 + u_4 - u_5$. Clearly $z_0 = z_2 = z_4$ and these are numerically equal to z_1, z_3 and z_5 but with reversed sign.

No such simple short cut appears to exist if there are 8 or 12 observations, but fortunately, for quite non-mathematical reasons, British ships work in four-hour watches.

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*JAMESON, H.; Summary of investigations on the diurnal variation of barometer pressure in tropical seas. *Quart. J. R. met. Soc., London,* **67**, 1941, p. 157.

If r is the range between the greatest and least of the six quantities, $u_0, u_1, \ldots u_5$, it is better to use z/r rather than z, since z/r is numerical and independent of the dimensions of u and z.

Clearly, small values of z/r suggest real periodicities, but do not prove their existence. On occasion a value of $z = 0$ can occur quite fortuitously.

Theoretical considerations indicate that with perfectly random values of $u_0, u_1, \ldots u_5$ the mean value of z/r from a sufficient number of sets of u may be expected to be 0·133, or, since z occurs as $6z$, it may be put more conveniently as $6z/r = 0{\cdot}8$.

I have not burdened this letter with the algebra of the above, but should be happy to discuss it with anyone who might be interested.

If n sets, each of six observations are available, it is easy to find $6z/r$ for each set and hence its average for the whole group.

Unless this mean value is less than 0·8 there seems little point in attempting further analysis by diurnal and semi-diurnal periods. As a small or even zero value of z may occur by chance, the practical question is: how great must n be to provide a reasonable basis? and for any particular value of n, by how much must the mean of $6z/r$ be below 0·8 to justify the use of the sine curve?

There is no absolute rule, but a rough guide has been provided by taking 120 sets of random u's. (Actually each u was the sum of 6 digits taken from the last column of various mathematical tables.) For each set $6z/r$ was obtained, and their mean values taken in successive groups of 2, 3, 4, 5, 6, 8, 10, etc. The mean value of $6z/r$ for the whole 120 groups was 0·797 or almost exactly the theoretical value. In two cases $z = 0$.

For each group of n sets, $120/n$ values of $6z/r$ were thus obtained and plotted; thus the least value of $6z/r$ corresponding to any particular value of n could be read off at once. Admittedly a second experiment with other random data would not give identical figures, but the general smoothness of the graph, including the way in which the 25 percentiles fit in with the factor $1/\sqrt{(n-1)}$, suggests that the 120 sets used were adequate to give a reasonable working basis.

These suggest that for over 15 groups a value of $6z/r$ of less than 0·7 is most unlikely to occur without a real systematic cause that justifies the use of the sine curve. For $n = 10$ the same is true if $6z/r$ is not greater than 0·5, while between 0·7 and 0·5 there appears to be at least a 3 to 1 chance that it is true.

With less than 8 groups it would probably not be wise to make deductions, though in the experiment in question the lowest value of $6z/r$ when $n = 6$ was 0·45.

A further point is the interpretation of values of $6z/r$ considerably above 0·8. Presumably they suggest a systematic cause at work, but one that can be expressed more descriptively by other means than the sine curves in question. A consistent increase at a particular watch only, the other five values of u being identical, would be a case in point, and would give $6z/r = 1{\cdot}0$.

A. J. BAMFORD

19, *Little Paddocks, Ferring, Sussex, July* 4, 1948

Unusual condensation trails

I was interested in the letter from Mr. Dight in your May issue giving an account of other cases of condensation trails formed by the propellors. The point I wished to emphasise, however, in my report of the events of November 29, 1947,* was not the formation of trails by the propellors, which has occurred on other flights from this station, but the formation of ice on the wings where the condensation trails streamed back over them and nowhere else on the aircraft.

I believe that is the first observation of ice accretion formed from a condensation trail. It supports the recently introduced practice of calculating relative humidity and humidity-mixing ratio with respect to a water surface at all temperatures.

E. R. RIPLEY

West Malling, August 5, 1948

NOTES AND NEWS

Very heavy rainfall in Tanganyika

Very heavy rain occurred at Christmas time at Kisawasawa in Tanganyika, over 18 in. falling in two days, causing a landslide and killing several people. Fr. Kosmas at the Kisawasawa Mission (7°51′S. 36°56′E. 900 ft.) reports :—

" The rain began on the 24th at 6.30 p.m. and with the exception of about an hour at midnight continued till 9 a.m. on the 25th. During Christmas Day the sun was shining. But in the evening at 6.30 the rain began again and it was very heavy rain right through the night till 7.30 a.m. of the 26th. Just about after midnight (or at 1 a.m. of 26th) the landslide had happened.

" This heavy rainfall was only local, in length not more than two miles beginning about at the Chonde river on the Kilosa side and passing one mile beyond the Kisawasawa river towards Kiberege."

Although the extremely heavy rainfall was only local, instability conditions were more widespread as shown by the following rainfall reports:—

	Position		Height	Rainfall 24th–25th	Rainfall 25th–26th
			ft.	in.	in.
Kisawasawa Mission	7°51′S.	36°56′E.	900	6·67	11·98
Ruaha Mission	—	—	—	3·70	5·00
Ifakara Mission	8°09′S.	36°39′E.	900	2·01	4·22
Tunungao Mission	7°03′S.	37°58′E.	570	0·23	3·94
Kidodi Mission	7°35′S.	37°02′E.	1,100	0·21	1·98
Matombo Mission	7°05′S.	37°46′E.	1,270	1·11	1·20
Ilula Mission	7°40′S.	36°00′E.	4,500	0	1·58

Mr. Grinsted, acting Director, East African Meteorological Service, comments that there was an active convergence zone over the area and that 18 in. of rain in two days is a great deal even for Tanganyika.

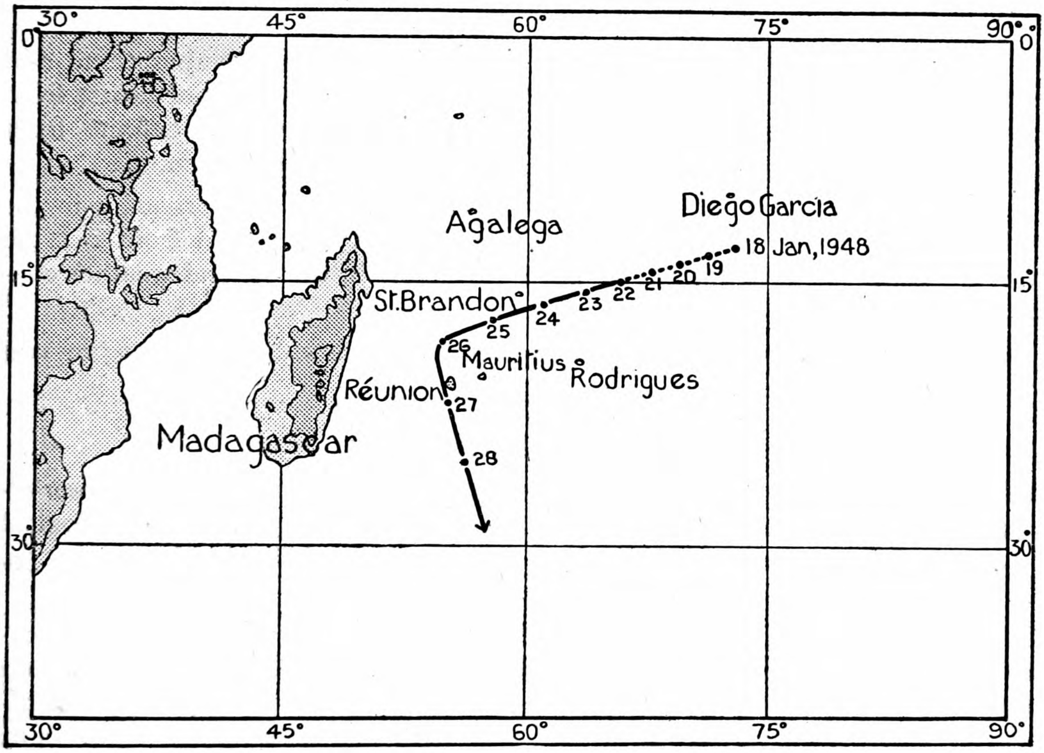
Met. Mag., London*, **77, 1948, p. 17.

Tropical cyclone, south-west Indian Ocean, January 1948

A severe cyclone caused serious damage in the St. Brandon group of islands, (dependency of Mauritius) and at Réunion between January 24 and 27, 1948.

The following statement is a summary of a report on the storm for which we are indebted to Mr. E. C. Davy, Acting Director of the Mauritius Observatory.

First indications of the instability associated with the formation of the storm were a fall of pressure by 1 mb. and unsettled weather at Diego Garcia (see Fig. 1) on the 18th. No centre was located until the 23rd when observations of slowly falling pressure and wind veering from SE. to SW. at St. Brandon and on a ship 50 miles to the east, suggested the existence of a depression centred about 15°S.64°E. During the 24th wind blew at gale to hurricane force at St. Brandon while changing direction from SW. to NW. The reading of a mercury barometer fell to 959 mb. at 1200 G.M.T. and the wind was estimated at the same time to be 125 m.p.h. Part of the eye of the storm was experienced at Long Island, 22 miles south-east of the meteorological station at St. Brandon. At Avocaire, only 13 miles south-east of the meteorological station, the lowest pressure (read on an aneroid) was 940 mb. at about 1200 G.M.T. There was no decrease of wind at the time of this reading. Two islands in the St. Brandon group were washed away and six lives were lost.



On the morning of the 26th the centre was situated at 18¾°S.54¾°E. and the recurve towards south and south-east started. The cyclone then moved south-south-east almost over Réunion. Pressure at Réunion fell to 960 mb. and the wind there blowing at hurricane force, changed direction from E. to NE. as the centre passed by. It is known that there was considerable loss of life and material damage at Réunion but full information was not available to Mr. Davy when writing his report.

The cyclone passed Mauritius at a distance of 100 miles. The highest gust recorded there was one of 57 m.p.h.

Mr. Davy considers the cyclone as one of the most intense known in the south Indian Ocean. There is good reason to believe the central pressure was below 940 mb. which compares with readings in the central calm of earlier cyclones of 953 mb. at Mauritius in January 1945 and 947 mb. in 1892.

Tornado, Co. Kildare, Eire

Newspaper cuttings (*Irish Independent* and *Leinster Leader*) have been received from the Director of the Meteorological Service of Eire and from Mr. Walsh, Principal of the Irish Nautical College, Dublin, describing events at Palmerstown House, Kill, Co. Kildare, at 2.30 p.m. on May 31, 1948.

Palmerstown House is a horse-training establishment. A whirlwind is stated to have struck it " with a shrill whistling sound followed by the noise of falling trees ". Previously there had not been much wind and only light rainfall. The roof of a long line of horse boxes was torn away, heavy supports smashed, and concrete blocks ripped from the walls. Joists from the stables were found half a mile away. In the grounds full-size beech trees were torn up by the roots. One beech tree was snapped off at ground level and carried 30 yd. The trail of damage was about 800 yd. long. One tree had its branches slashed downwards while others nearby were undamaged.

Fresh polar air covered Ireland on May 31 and cumulonimbus cloud and squally showers were general. A shallow depression moved north-east from central Ireland to north-west England during the day. No definite front could be traced as crossing Kildare at the time of the phenomenon.

The events seem to have been due to a small tornado. Tornadoes in the British Isles have generally been associated with a sharp cold front but the occurrence of one would not have been impossible in the general weather conditions of May 31.

The report is of interest as a search through the literature revealed no previous record of a tornado in Ireland.

REVIEWS

Mikroklimatikus mérések dohányban és napraforgóban (Microclimatological observations on tobacco and sunflower), by D. Berényi. Bulletin of the Meteorological Institute of the University of Debrecen, No. 8. 8vo, 9½ in. × 6¾ in. pp. 59. Debrecen, 1948.

This bulletin contains two papers, the first of which gives the results of experiments on the microclimate of tobacco with different plant-spacing and also on the microclimate of two varieties of tobacco. In these experiments air temperatures in the crops were measured with standard station thermometers at heights of 5, 100, 150 cm., and the soil temperature at a depth of 5 cm. A hair hygrometer and a Piché evaporimeter were used to give measurements of humidity and evaporation at 5 and 150 cm. Temperatures were also measured at 5 and 150 cm. in an open situation outside the crops. Observations were made every hour from 0800 to 2000.

The plant-spacings compared were 70 × 50 cm. and 60 × 40 cm. and a comparison of the mean hourly temperatures over 7 days leads to no unexpected results. At 5 cm. the mean daily temperature in the open is 0·2°C. higher than in the widely spaced crop and 0·9°C. higher than in the closely spaced. The greatest difference is at 1400 when the mean temperature in the open is 1·0°C. higher than in the 70 × 50 cm. crop and 2·1°C. higher than in the 60 × 40 cm. At 150 cm. the differences are much smaller. Spacing affects the soil temperature at 5 cm. which is 0·5°C. higher under the wider than under the closer spacing; in the middle of the day the mean differences reach 1°C.

Evaporation and saturation deficits over the whole day are greater in the wider spacing both at 5 cm. and 150 cm. but differences in relative humidity are only slight. The vapour pressure at 5 cm. is greater in the widely spaced crop, but at 150 cm. it is greater in the closer spacing. Although these results may be true for the day as a whole, it is sometimes difficult to reconcile the mean hourly values given by the author in various tables.

The second experiment was arranged to find the difference between the microclimates of Debreceni and Szabolcsi varieties of tobacco with both of them planted at intervals of 60 × 40 cm. Air temperatures, soil temperatures and evaporation are higher in the Debreceni crop and the author therefore concludes that the Szabolcsi variety is more suitable in dry regions.

The second paper gives the results of measurements in sunflower (spacing 70 × 60 cm.) and in Debreceni tobacco. The height of the sunflower, 2·5–3 m., prevents the air near the soil from warming up until late in the forenoon and it is cooler at 5 cm. than at 300 cm. until about 0900, and also after about 1700.

Some comparison is given between various heights in sunflower, tobacco and in the open field, but differences in the heights make it difficult to draw any conclusions from the results. There may well be good reasons for taking observations at 300, 150 and 20 cm. in the sunflower and at 150, 100 and 5 cm. in tobacco and in the open, but unfortunately they are not mentioned in the English summary. It is therefore difficult to accept with confidence the conclusion: " Tobacco has a more extreme microclimate than sunflower, and this is characterised by a quick cooling down and a stronger warming up."

The English summaries must be used with some care and the statements should always be checked against the tables and diagrams. No doubt some of the difficulties are purely linguistic, but others appear to be due to inadequate statistical analysis of results. Two examples of this are given below:—

(i) On p. 28 § 9(*c*) it is stated that the increase of evaporation at 5 cm. is 19 per cent. greater in the closely spaced tobacco than in the widely spaced (relative to the air temperature at 150 cm. in the open). This statement is based on the regression equations given on p. 20, viz.:—

$$\text{Evaporation (wide spacing)} = 0{\cdot}023\ T - 0{\cdot}25$$
$$\text{Evaporation (close spacing)} = 0{\cdot}0273\ T - 0{\cdot}41$$

where T is the temperature in the open. These regression lines are shown in Fig. 29, but as the standard errors of the regression coefficients are not given, it is impossible to judge whether the lines are significantly different.

(ii) On p. 53 § 1, it is stated that wind has a significant role in the development of the vertical temperature gradients, though cloudiness has obviously more influence. However, the correlation coefficient between the mean lapse in the sunflower crop and the mean wind force is only about 0·30, which would be expected about 3 times out of 10 by chance, even if there were no correlation between the observations. The correlation coefficient between the temperature lapse and cloudiness is about 0·58, which would not be expected as frequently as once in 20 times by chance and can therefore be taken as significant.

There is, however, no doubt of the value of the experiments which have been carried out by Professor Berényi, experiments which must be repeated in other crops and with carefully planned replication. It will then be possible to assess within definable limits the effect of different crops and cultural practices on the microclimate of any locality.

W. H. HOGG

A contribution to the study of storm surges on the Dutch coast, by W. F. Schalkwijk. *Meded. Verh. Ned. met. Inst.*, *De Bilt*, Serie B, **1**, Nr. 7. 4to. 12½ in. × 9 in. pp. iv + 111. Rijksuitgeverij/'s-Gravenhage, 1947. Price 10 *florins*.

The term " storm surge " is used to denote changes of sea level associated with meteorological factors. The observed tide at a place may differ from the astronomical or predicted tide, the difference depending upon the meteorological elements wind and atmospheric pressure. When this difference is additive and occurs at or near the time of high tide coastal defences may be threatened. The economic importance of a " Warning service for storm surges " in a country like Holland is at once apparent.

Interest in the subject in this country was given an impetus by the disastrous floods in the Thames during the night of January 6–7, 1928, reports being made by Doodson and Dines*. Later work has been done by Doodson, Proudman and Corkan.

The present contribution starts with a useful historical survey of considerable interest to the meteorologist and requiring no specialised knowledge. The theory of the wind effect is then developed from the fundamental equations, assuming a stationary homogeneous wind field, and applied to the cases of an enclosed sea and a bay, the latter representing the idealised form of the North Sea, regarded as closed at its southern end; the modifying effect of the English Channel is shown to be small. Investigations are later made on the effect of a non-homogeneous wind field and a non-stationary state.

The application of these results to selected storm surges is then considered in detail, values of wind over the North Sea being deduced from synoptic charts. The agreement found between the theoretical and empirical results is as high as could be expected bearing in mind the various approximations used. The author gives plausible reasons for the discrepancies and for the differences between the present and previous investigations.

Most forecasting rules used in the past have been statistical in character. The aim of this work is the derivation of a general method of predicting the development of individual storm surges from the expected development of the barometric field. This change in outlook is of great importance.

T. H. KIRK

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*DOODSON, A. T.; Report on the Thames floods, and DINES, J. S.; Meteorological conditions associated with high tides in the Thames. *Geophys. Mem., London*, **5**, No. 47, 1929.

Catalogue No. 684. *Meteorological and Scientific Instruments.* C. F. Casella & Co., Regent House, Fitzroy Square, W.1.

Messrs. Casella's new catalogue is issued with price list No. 699, dated June 1948. To their extensive range of meteorological instruments Messrs. Casella have now added the Gold visibility meter and the Duvdevani dew gauge. Besides details of the instruments the catalogue contains much sound advice on their exposure and reading.

NEWS IN BRIEF

The L.G. Groves Memorial Prize for Meteorology has been awarded this year to Dr. Ronald Frith, Principal Scientific Officer in the Meteorological Office, for his valuable services rendered as senior Meteorological Officer of the Meteorological Research Flight.

Mr. J. K. Bannon was announced as *proxime accessit.*

The L.G. Groves Memorial award for Meteorological Air Observers has been won this year by Flight Sergeant P. G. White, R.A.F.V.R. Meteorological Observer, for meritorious work and devotion to duty.

The presentation ceremony took place in the Air Member for Personnel's room on October 19, 1943. The presentations were made personally by Major Groves who was accompanied by Mrs. Groves.

We have received a letter from the Occupational Therapist at Napsbury Hospital, near St. Albans, saying that she would like to run a simple form of meteorological station for the patients. The main point in this connexion is that they should feel that the work is of some use outside the hospital. The major difficulty is the price of instruments. If any readers have a standard 5-in. rain-gauge or thermometers, with N.P.L. certificates, which they no longer require and would be willing to present them to the hospital will they please communicate with:—

Miss Mary K. Goodman, Occupational Therapist,
28 Sandringham Road, Bromley, Kent.

WEATHER OF SEPTEMBER 1948

Many depressions moved north-eastwards between Scotland and Iceland and three eastwards across the British Isles, crossing northern England on the 3rd and 15th and southern England on the 12th. After the 15th anticyclones were centred over or near to England, mostly over the Channel or its western approaches, but over central Europe from the 23rd to the 28th.

Mean pressure for the month was below 1005 mb. from southward of Iceland to northern Norway, and 1020 mb., or slightly over, in northern France and south-westwards beyond the Azores. It was more than 5 mb. below normal between north-east Scotland and northern Scandinavia but generally within about 2 mb. of normal in an area extending from the eastern parts of the U.S.A. to Russia and the Mediterranean.

In the British Isles unsettled weather prevailed generally for the first half of the month. Subsequently anticyclonic conditions were established over southern England and continued until the end of the month, apart from a break on the 27th–28th. Unsettled conditions persisted, however, in the west and north. It is interesting to note that whereas the number of days without measurable rain at Stornoway in the northern Hebrides was only one, at some stations in south-east England the number was 22.

During the opening days an Atlantic depression moved east across northern England to the North Sea and filled. Heavy rain occurred in western districts on the 1st and more generally on the 2nd, with the local thunderstorms in the west. Showers and scattered thunderstorms occurred on the 3rd and 4th. On the 7th and 8th an anticyclone over the Bay of Biscay moved north-east, while a depression westward of Scotland moved rather quickly north-east to the north of Norway. Strong winds occurred in the west and north, reaching gale force locally and rain fell at times, particularly in the west on the 7th and in the neighbourhood of a slow-moving front stretching from north-east England to south Wales on the 8th. Temperature rose and touched 79°F. in parts of London on the 9th. In the following days a new depression on the Atlantic moved north-north-east, while associated troughs crossed the British Isles giving further rain. On the 12th a small depression moving across southern England was associated with considerable rain there, while on the 14th and 15th another small disturbance moved rapidly east-north-east from mid Atlantic across southern Scotland to the North Sea, giving rain, heavy in places, in the northern half of the country. Gales were recorded locally on the 12th, 13th and 15th. Subsequently an anticyclone became established off our south-west coasts and dominated conditions over England until the 19th, when a cold front moved south over the country giving some slight rain in the west and north. Thereafter another anticyclone situated south-east of Greenland, moving rather quickly south-east, reinforced the one off our south-west coasts, and cool weather prevailed, with scattered rain, chiefly in the west and north. Slight screen frost occurred locally on the 21st and 22nd and in Scotland also on the 23rd, with ground frost in many places. By the 24th the highest pressure was situated over central Europe and a wedge extended west over southern England. Meanwhile the north-east Atlantic was covered by a complex area of low pressure and the air supply over the British Isles was drawn from the south; temperature rose appreciably and approached 80°F. in parts of London on the 26th. From the 26th to 28th vigorous depressions moved north-east along our north-west seaboard; gales occurred in the north-west and north and considerable rain fell in Scotland, north Ireland and northern England on the 26th. Some slight rain fell also in southern England on the 27th and 28th. Apart from slight showers in the north-west and north fair weather prevailed during the closing days but a trough of low pressure moving north-east over north-west Scotland brought further rain in the north-west late on the 30th.

The general character of the weather is shown by the following table:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days' difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	79	27	+0·9	113	0	87	33
Scotland	72	21	+0·7	156	+5	93	29
Northern Ireland..	70	33	+1·2	146	+5	80	25

RAINFALL OF SEPTEMBER 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·34	74	*Glam.*	Cardiff, Penylan ..	4·18	137
Kent	Folkestone, Cherry Gdns.	2·55	108	*Pemb.*	St. Ann's Head ..	3·12	109
,,	Edenbridge, Falconhurst	2·08	92	*Card.*	Aberystwyth	3·65	128
Sussex	Compton, Compton Ho.	3·76	135	*Radnor*	Bir. W. W., Tyrmynydd	5·30	137
,,	Worthing, Beach Ho.Pk.	1·63	76	*Mont.*	Lake Vyrnwy	4·95	131
Hants	Ventnor, Roy. Nat. Hos.	1·54	62	*Mer.*	Blaenau Festiniog ..	16·34	207
,,	Bournemouth	2·50	107	*Carn.*	Llandudno	2·01	94
,,	Sherborne St. John ..	2·20	107	*Angl.*	Llanerchymedd ..	3·76	128
Herts.	Royston, Therfield Rec.	1·88	100	*I. Man.*	Douglas, Boro' Cem. ..	5·40	165
Bucks.	Slough, Upton	1·73	98	*Wigtown*	Port William, Monreith	4·72	162
Oxford	Oxford, Radcliffe ..	2·48	145	*Dumf.*	Dumfries, Crichton R.I.	4·93	182
N'hant.	Wellingboro', Swanspool	2·18	121	,,	Eskdalemuir Obsy. ..	6·97	186
Essex	Shoeburyness	·98	59	*Roxb.*	Kelso, Floors	2·42	127
Suffolk	Campsea Ashe, High Ho.	1·79	94	*Peebles*	Stobo Castle	3·60	143
,,	Lowestoft Sec. School ..	·90	46	*Berwick*	Marchmont House ..	2·41	100
,,	Bury St. Ed., Westley H.	1·47	74	*E. Loth.*	North Berwick Res. ..	2·58	123
Norfolk	Sandringham Ho. Gdns.	2·31	112	*Midl'n.*	Edinburgh, Blackf'd. H.	2·58	126
Wilts.	Bishops Cannings ..	2·32	106	*Lanark*	Hamilton W. W., T'nhill	5·87	219
Dorset	Creech Grange.. ..	3·18	116	*Ayr*	Colmonell, Knockdolian	4·69	135
,,	Beaminster, East St. ..	3·19	125	,,	Glen Afton, Ayr San ..	5·96	153
Devon	Teignmouth, Den Gdns.	1·22	62	*Bute*	Rothesay, Ardencraig	8·39	207
,,	Cullompton	1·58	70	*Argyll*	L. Sunart, Glenborrodale	10·26	164
,,	Barnstaple, N. Dev. Ath.	2·21	82	,,	Poltalloch	8·96	196
,,	Okehampton, Uplands	2·44	75	,,	Inverary Castle.. ..	13·86	216
Cornwall	Bude School House ..	1·80	73	,,	Islay, Eallabus ..	7·20	172
,,	Penzance, Morrab Gdns.	1·86	63	,,	Tiree	6·65	179
,,	St. Austell, Trevarna ..	2·45	77	*Kinross*	Loch Leven Sluice ..	4·11	160
,,	Scilly, Tresco Abbey ..	·90	35	*Fife*	Leuchars Airfield ..	2·67	138
Glos.	Cirencester	2·54	115	*Perth*	Loch Dhu	11·42	199
Salop.	Church Stretton ..	2·58	122	,,	Crieff, Strathearn Hyd.	..	..
,,	Cheswardine Hall ..	3·24	159	,,	Pitlochry, Fincastle ..	3·56	142
Staffs.	Leek, Wall Grange P.S.	2·02	81	*Angus*	Montrose, Sunnyside ..	1·93	97
Worcs.	Malvern, Free Library	2·75	143	*Aberd.*	Balmoral Castle Gdns...	1·80	75
Warwick	Birmingham, Edgbaston	2·81	157	,,	Dyce, Craibstone ..	1·81	75
Leics.	Thornton Reservoir ..	2·61	144	,,	Fyvie Castle	1·96	75
Lincs.	Boston, Skirbeck ..	2·31	131	*Moray*	Gordon Castle	2·57	103
,,	Skegness, Marine Gdns.	2·68	148	*Nairn*	Nairn, Achareidh ..	2·40	114
Notts.	Mansfield, Carr Bank ..	2·25	122	*Inv's*	Loch Ness, Foyers ..	4·42	150
Ches.	Bidston Observatory ..	1·62	67	,,	Glenquoich	15·65	181
Lancs.	Manchester, Whit. Park	2·10	88	,,	Fort William, Teviot ..	13·78	216
,,	Stonyhurst College ..	4·06	106	,,	Skye, Duntuilm ..	8·74	190
,,	Blackpool	4·60	161	*R. & C.*	Ullapool	4·62	127
Yorks.	Wakefield, Clarence Pk.	1·14	71	,,	Applecross Gardens ..	8·96	179
,,	Hull, Pearson Park ..	1·35	78	,,	Achnashellach	11·93	173
,,	Felixkirk, Mt. St. John	1·82	100	,,	Stornoway Airfield ..	7·18	191
,,	York Museum	1·20	74	*Suth.*	Lairg	3·61	128
,,	Scarborough	1·54	86	,,	Loch More, Achfary ..	11·73	204
,,	Middlesbrough.. ..	1·17	71	*Caith.*	Wick Airfield	3·10	124
,,	Baldersdale, Hury Res.	3·87	155	*Shet.*	Lerwick Observatory ..	5·64	187
Norl'd.	Newcastle, Leazes Pk. ..	3·66	185	*Ferm.*	Crom Castle	3·77	135
,,	Bellingham, High Green	3·97	165	*Armagh*	Armagh Observatory ..	2·64	107
,,	Lilburn Tower Gdns. ..	1·98	84	*Down*	Seaforde	3·16	115
Cumb.	Geltsdale	5·08	181	*Antrim*	Aldergrove Airfield ..	4·30	173
,,	Keswick, High Hill ..	6·97	165	,,	Ballymena, Harryville..	4·51	145
,,	Ravenglass, The Grove	5·70	169	*Lon.*	Garvagh, Moneydig ..	4·49	151
Mon.	Abergavenny Larchfield	2·81	120	,,	Londonderry, Creggan	6·16	187
Glam.	Ystalyfera, Wern House	8·76	200	*Tyrone*	Omagh, Edenfel ..	4·78	157

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, MAY 1948

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation			Bright Sunshine	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1015·5	−0·1	77	34	63·5	45·7	54·6	−0·1	49·9	70	5·5	2·22	+0·50	9	7·5	48
Gibraltar	1014·9	−1·2	81	51	72·1	59·0	65·5	0·0	60·4	76	5·3	2·87	—	10	8·6	61
Malta	1013·7	−0·8	81	54	74·8	60·9	67·9	+2·0	64·2	68	3·7	0·08	—	2	9·8	70
St. Helena	1016·6	−0·3	70	56	68·3	58·5	63·4	+0·8	59·0	93	8·5	2·08	−0·46	13	—	—
Freetown, Sierra Leone	1011·8	+2·2	89	69	85·0	75·0	80·0	−0·5	76·1	82	6·6	7·70	−3·77	15	5·8	46
Lagos, Nigeria	1011·5	+0·9	92	69	88·1	72·4	80·3	−1·5	77·7	85	8·6	8·98	—	15	4·4	35
Kaduna, Nigeria	1009·3	—	94	64	87·8	69·9	78·9	−1·0	73·1	76	8·3	4·89	−0·88	11	7·1	56
Chileka, Nyasaland	1019·1	+0·1	85	53	78·5	59·5	69·0	+1·0	63·4	69	3·8	0·06	−0·24	3	7·7	67
Lusaka, Rhodesia	1016·4	+0·4	84	50	78·5	55·2	66·9	+1·8	59·8	65	3·1	0·19	+0·14	2	9·8	86
Salisbury, Rhodesia	1019·0	+0·3	81	43	73·8	49·6	61·7	+0·6	56·3	68	1·9	0·67	+0·29	2	9·1	81
Cape Town	1017·3	−0·8	81	44	69·0	53·6	61·3	+2·4	53·4	78	7·0	4·00	+0·25	16	—	—
Germiston, South Africa	1032·5	—	71	37	66·9	45·3	56·1	—	47·1	72	2·7	0·58	—	3	9·3	86
Mauritius																
Calcutta, Alipore Obsy.	1001·6	−2·0	98	71	93·4	79·0	86·2	+0·1	80·8	80	6·8	3·78	−1·78	12	8·1	61
Bombay	1006·5	−0·9	94	79	92·5	81·7	87·1	+1·3	78·0	71	4·4	0·00	−0·55	0	9·8	75
Madras	1004·0	−1·4	110	77	102·0	83·7	92·9	+3·1	78·3	62	5·2	0·32	−1·52	2	9·5	75
Colombo, Ceylon	1008·9	+0·5	89	73	87·4	78·3	82·9	+0·1	78·1	87	7·5	6·60	−4·34	25	6·3	51
Singapore	1008·7	0·0	95	73	89·5	75·9	82·7	+0·7	77·1	83	6·6	9·75	+3·11	18	—	—
Hong Kong	1010·1	+1·0	92	69	83·8	74·9	79·3	+1·9	76·0	88	—	9·14	−2·93	26	4·9	37
Sydney, N.S.W.	1016·1	−2·5	78	44	67·5	51·1	59·3	+0·5	51·4	67	3·6	5·31	+0·13	6	7·3	70
Melbourne	1016·5	−2·7	75	41	59·5	47·0	53·3	−0·8	49·7	81	6·8	1·83	−0·33	18	2·8	28
Adelaide	1021·1	+0·9	81	42	63·3	50·7	57·0	−1·0	51·8	73	6·9	3·11	+0·39	17	4·0	39
Perth, W. Australia	1022·1	+3·7	83	47	72·6	51·4	62·0	+1·3	56·0	61	3·0	1·04	−3·93	9	6·7	64
Coolgardie	1023·8	+4·7	82	37	69·9	45·7	57·8	+0·1	50·1	61	2·3	0·01	−1·32	1	—	—
Brisbane	1017·2	−1·4	83	43	73·5	53·7	63·6	−1·0	55·9	59	2·7	4·90	+2·09	6	8·4	78
Hobart, Tasmania	1009·3	−6·0	65	38	55·3	43·2	49·3	−1·2	44·7	73	7·5	2·46	+0·56	18	3·4	35
Wellington, N.Z.	1009·1	−6·5	63	40	56·8	47·4	52·1	+0·7	49·9	82	7·5	7·92	+3·24	21	3·6	36
Suva, Fiji	1012·1	−0·6	87	64	81·4	71·5	76·5	0·0	73·2	84	7·1	7·93	−2·14	20	5·4	48
Apia, Samoa	1010·5	−0·2	90	72	86·3	74·8	80·5	+0·8	77·8	82	7·8	10·63	+4·10	29	5·9	51
Kingston, Jamaica	1012·5	−0·6	91	70	88·8	74·4	81·6	+1·9	75·9	76	5·0	9·21	+4·82	7	7·8	60
Grenada, W. Indies	—	—	88	73	86·4	76·6	81·5	+1·8	77·9	81	8·3	2·60	−1·59	16	—	—
Toronto	1013·6	−1·3	75	35	61·4	45·2	53·3	−0·5	45·2	68	6·6	2·64	−0·15	12	6·9	47
Winnipeg	1016·0	+2·2	95	24	67·2	40·7	53·9	+1·9	41·0	72	3·9	1·70	−0·30	4	7·3	47
St. John, N.B.	1014·2	+0·3	68	32	54·8	40·4	47·6	−0·1	44·2	85	8·3	5·09	+1·38	21	4·5	30
Victoria, B.C.	1014·8	−1·9	76	33	59·9	45·3	52·6	−0·4	46·0	92	7·6	4·02	+2·89	16	7·3	48

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ASSEMBLY OF THE U.G.G.I. AT OSLO, AUGUST 1948

BY C. S. DURST, B.A.

The International Union of Geodesy and Geophysics (U.G.G.I. as it is usually called) is a confederation of several international Associations and Commissions whose object is, by international co-operation, to further scientific research and investigation in their various fields of geodetic and geophysical study. At the present time there are seven of these constituent international Associations concerned with the following subjects: (1) geodesy, (2) seismology, (3) meteorology, (4) terrestrial magnetism and electricity, (5) oceanography, (6) vulcanology and (7) hydrology. These organizations function more or less autonomously within the Union.

The U.G.G.I. is one of nine international scientific unions which adhere to the International Council of Scientific Unions (I.C.S.U.), and through this Council the U.G.G.I. adheres to the United Nations Economic, Social and Cultural Organization (U.N.E.S.C.O.).

The U.G.G.I. and its component Associations and Commissions normally meet in General Assembly every three years. Assemblies have been held in Rome (1922), Madrid (1924), Prague (1927), Stockholm (1930), Lisbon (1933), Edinburgh (1936) and Washington (1939). The outbreak of war seriously interfered with the last assembly, and that held in Oslo from August 19 to 28, 1948 has had to link up threads over a gap of nine years.

The usual procedure at a General Assembly is for all delegates to meet at an opening session, after which the several Associations adjourn to separate meeting places for their own business and scientific discussions. At the end of the Assembly all the delegates meet again to agree on important major resolutions and decisions, and also to conduct the business of the Union such as the election of officers.

Such is in broad outline the function of U.G.G.I. In the third week of last August there converged on Oslo 400 delegates from 37 nations by railway, steamship and plane. The British delegation was the most numerous with 62 members, the U.S.A. had a membership of 51, and there were delegates from as far afield as the Philippines, Ecuador and Iceland.

The present writer arrived in a plane load of scientists on the 18th.

Our first sight of Norway was of sunlit islands fringing the southern coast around Christiansund but by the time the plane had turned into Oslo Fjord the frontal clouds had closed down and we landed in teeming rain. That was typical of the Norwegian weather we experienced ; rain which did its best to spoil expeditions, and periods of bright sunshine with amazing visibilities over the mountain tops. But, whatever the weather, there was no lack of warmth and welcome in the entertainment which our Norwegian hosts provided for us and which they crowned with a marvellously planned meteorological excursion at the conclusion of the Congress, an excursion which carried us through the heart of the Jotunheim and to the summit of Fanaråken and finally bore us on board the Norwegian ocean weather ship *Polarfront I* down the Sogn Fjord to be welcomed and speeded home from Bergen.

The Oslo Assembly was held in the University buildings, and there in the gaily painted Aula the opening ceremony was performed on August 19 in the presence of the King of Norway. There we assembled to hear speeches of welcome interspersed with orchestral music and an eloquent reply by Dr. Norlund, Acting President of the Union.

That ceremony ended, the Conference broke up into its several Associations, often with congested programmes which could hardly be compressed into three-hourly sessions, morning and afternoon, throughout the seven working days.

The Meteorological Association was presided over by Prof. S. Chapman with Prof. J. Bjerknes as Secretary. However, in response to a request by these officers, a change was made when Prof. J. Bjerknes was elected president and Prof. J. van Mieghem (Belgium) was chosen Secretary.

In his presidential address Prof. Chapman made a strong case for an International Meteorological Research Organization to link together the various meteorological research bodies throughout the world and to serve as a clearing house for ideas. He took as his pattern the British Meteorological Research Committee, and urged that there were many problems which could be far more satisfactorily handed over to an international body than left to the efforts of the national organizations. Among such problems he cited those concerned with the computation of forecasts by electronic methods, the world-wide examination of the effects of ozone and the further discussion of lunar and solar tides in the atmosphere.

In a brief space it is not possible to describe the many notable lectures which were given to the Meteorological Association but, looking back, the most outstanding impression was that created by the discussions on rain-making by artificial means. Early in the Conference a pronouncement was given by Dr. Reichelderfer (U.S.A.) that, in all the experiments made in the United States, there was no recorded case in which seeding a cloud with dry ice, had produced rain when rain from natural causes had not fallen within 30 miles. He confirmed that cloud had been dissipated locally by the use of dry ice, but it was doubted whether there was in fact any practical possibility of rain-making on an extensive scale. The same conclusion was reached in a masterly exposition by Prof. Bergeron (Sweden) who enumerated the cloud types from which precipitation might be derived by suitable seeding. He emphasised, however, that excessive seeding might actually prevent precipitation. Then he went on to point out that in some topographical situations, where the artificial production of rain might be most effective on physical grounds, there was already a superabundance of natural precipitation and suggested the possibility that overseeding in those regions might be used to prevent the clouds shedding their water on the windward side of hills with consequent benefit to the drier localities to leeward. Dr. Pawsey of Australia was more optimistic on the economic aspect of rain-making and cited the case* in which precipitation had been actually produced by skilful seeding, precipitation which had been sufficient in amount to fill the dry water-storage tank of an Australian farmhouse.

A contribution which was generally accepted by the delegates as being of major importance was that given by Dr. Eady (Gt. Britain). He gave a resumé of his theory of selective unstable waves in an atmosphere limited by the boundaries of the tropopause and the earth's surface ; into this atmosphere there are introduced baroclinic cloud layers involving further boundary conditions. Computations based on his theory, he claimed, had shown a remarkable similarity to the facts of short-lived cyclonic formation and progression on the one hand and of long-period waves related to more persistent weather types on the other.

A most engrossing film was shown by Prof. Byers (U.S.A.), in which was exhibited, in slow motion, the records of the radar reflection from rain (on a P.P.I. screen) during thunderstorms over Florida. In them could be seen the cellular structure of the storms and the progressive developments of the rain areas. In a talk on the subject of the " Thunderstorm Project " Prof. Byers emphasised that for the development of a cumulonimbus cloud it was necessary that down currents be engendered and that cooling of air by rain played a very important part in the process. He further pointed out that the coldness of gusts connected with the arrival of a thunderstorm was due to air entrained into the down current during its descent.

Prof. Palmén (Finland) showed some interesting examples of jet streams†. He then went on to describe how in some circumstances a narrow tongue of cold tropospheric air might protrude southwards, and how the jet stream might cut across this tongue leaving to the south a region of low tropopause and high stratospheric temperature. In this region cyclonic rotation was present and on the eastern side of the region precipitation occurred.

A very clear statement of the fundamental problems in the study of radiation was given by Dr. Nicolet (France).

In conjunction with the Associations of Seismology and Oceanography one session was devoted to the discussion of microseisms. It was interesting to hear how successful the Americans had been in locating the positions and movements of tropical revolving storms by means of the microseisms recorded at two tripartite seismographic stations. Each tripartite station consists of three seismographs at distances of 200 or 300 m. from each other. From these the direction of the source can be discovered, and thus from two such tripartite stations the centre of the disturbance can be accurately plotted. The origin of the microseisms gave rise to several papers. Standing waves are

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*KRAUS, E. B. and SQUIRES, P.; Experiments on the stimulation of clouds to produce rain. *Nature, London*, 159, 1947, p. 489.

†PALMÉN, E.; On the distribution of temperature and wind in the upper westerlies. *J. Met., Lancaster, Pa.*, 5, 1948, p. 20.

formed by the crossing of swells formed in different quadrants of tropical storms and it may be demonstrated that standing-wave systems of this nature can produce pressure variations of half the period of the standing waves, even at the bottom of an ocean.

The density of the high atmosphere was ingeniously discussed by Dr. F. L. Whipple (U.S.A.). Simultaneous records are made of the passage of meteorites by photography, the records of the trail being interrupted at short intervals by a rotating shutter. The mass of the meteorite can be determined from its luminosity and velocity, the height being deduced from trigonometrical methods. The density of the atmosphere can then be deduced from the deceleration of the body. The velocity of the meteorites was found to vary from 50 or 60 m./sec. to 90 m./sec. It was stated that at the height at which meteorites occurred the density of the atmosphere was correlated to surface temperature. It would however appear that this was a seasonal effect. The ratio of the maximum density to the minimum density at those heights was about 3 : 1. Dr. Whipple gave a warning, however, against accepting these results with too much confidence. He pointed out that the values of density deduced depended on the luminosity of the body. If for some reason there was a seasonal variation in the luminosity this would seriously affect the conclusions.

Mr. A. W. Brewer (Great Britain) exhibited an automatically controlled hygrometer based on the design he and Dr. Dobson had evolved. He further gave a lecture on the results obtained by the dew-point hygrometer showing how greatly the water vapour decreased with height above the tropopause. From a rough calculation he estimated that a downward velocity of 50 m./day in the stratosphere would be necessary to maintain the distribution of water vapour if it is assumed that the coefficient of turbulence is about 10^3. This calculation was made on the assumption that there was no advection. Nevertheless the interesting feature is that assuming a not improbable value of the coefficient of turbulence the vertical velocities are of a not improbable value. One further comment may perhaps be allowed. The flights on which Mr. Brewer obtained his information were made mainly in long-track polar air, and hence there is a certain selectivity in the results he has obtained. The information Mr. Brewer gave created a profound effect on the delegates.

An interesting discussion was given by Major Bundgaard (U.S.A.) of the possibilities of statistical forecasting. His method is to take 500-mb. contour maps and submit them to a purely statistical analysis from which he obtains partial regression equations linking temporal and spatial values. From these regression equations it is possible to obtain the most probable future map, and moreover it is possible to obtain from the probable error a measure of the accuracy of the predictions. Major Bundgaard used his method in an attempt to predict the pressure pattern three days ahead, but his system being statistical can only take into account the probable translation of the systems. Development and abnormal deviations cannot be allowed for, and in three days much development may occur. The method if applied as a 24-hr. prontour might produce much more spectacular results.

From the list of notable contributions the two discussions introduced by Sir Nelson Johnson must not be omitted. The first was on the need for more observations of water vapour and of helium in the high atmosphere, and he enumerated from how many angles we were in want of these fundamental facts.

Going on he gave an account of our present knowledge and showed what very serious gaps there were. He urged that individual research workers should concentrate on these problems and develop a technique for their examination as he did not feel that the time was ripe for a mass attack on an international scale. The second discussion centred around antarctic meteorology. Sir Nelson Johnson reviewed the present activity in collecting information from high latitudes. He stated that the International Meteorological Organization had set up a Commission on polar meteorology under the presidency of Dr. Sverdrup and that co-operation was being sought from whaling vessels. He suggested that the International Meteorological Association might seek the co-operation of the International Meteorological Organization in the investigation of the meteorological problems of the Antarctic. He further proposed that workers engaged upon research in the ionospheric field should be invited to participate in the scheme. In the course of the subsequent discussion, the Argentine representative stated that his country was establishing two stations on the Antarctic continent.

The brief notes given above do not cover by any means all the many facets of meteorology which were discussed in the various sessions of the Meteorological Association. They will serve however to show how wide was the range of topics. At the conclusion of the meetings a number of resolutions were adopted by the Meteorological Association which covered among other points the setting up of two sub-commissions, one to be called the Ozone Sub-Commission, the other the Radiation Sub-Commission and names were proposed of persons to sit on these sub-commissions. It was further agreed that a grant should be made from the research vote towards the cost of work on the study of lunar and solar tides in the atmosphere. It was further agreed to adopt Sir Nelson Johnson's suggestion regarding the problem of the Antarctic, and also that the International Meteorological Association should request the International Meteorological Organization to arrange for full meteorological observations, including radio-sonde, to be carried out in any part of the world when mother-of-pearl clouds were observed.

The final plenary Assembly took place on the 28th at which various resolutions were passed by the Union as a whole and reports were made on the activities of the different Associations. The Acting President Prof. N. E. Norlund had asked to be relieved and Prof. Vening Meinesz, Director-General of the Dutch Meteorological Office was elected President for the next three years. Dr. J. M. Stagg was re-elected Secretary and it was announced that the next Assembly, in 1951, should be held in Brussels.

In such an assembly as this the mere narrating of the meetings of the Associations cannot give any idea of the full activities of the Union. It might well be said that more work is done out of sessions than in, for one of the great benefits derived from such meetings is the growth of personal contact at the many social functions with which the delegates were so lavishly entertained.

Notable among the entertainments must be mentioned the Sunday excursion to Lillehammer when almost all the delegates and their friends set out at an early hour in a special train on the 5-hr. journey. This gave ample time for the interchange of opinions—indeed on that train not a few unofficial scientific lectures were given over and above those that figured in the programme of the sessions. The weather did its best to mar the view, and on the motor trip which the Norwegian Government had planned for us over the mountains there was more opportunity for the study of drop-size distribution than for the measurement of the great ranges of visibility. However an excellent lunch was provided, and we studied (in dripping rain) the early Norwegian houses and the Stave Church of Maihaugen before once more boarding our train and travelling with polyglot babel back to midnight Oslo.

Other pleasant memories are of the reception of British delegates at the Embassy, the fountain and the view over Oslo Fjord and the welcome the Ambassador and Lady Collier accorded us, of " Peer Gynt " performed in a new setting at the National Theatre where our incomprehension of the words gave even greater music to the poetry, of the Vigeland statues in the Frogner Park and the discussions which they aroused, of one glorious evening on the Frognerseter hill with Oslo Fjord to the south and the mountains visible in line on line for 70 miles around, of Oslo port and the little ships that carried us across to visit the *Fram* and the wonderfully preserved Viking ships, and most of all of the fair-haired Norwegians smiling at our efforts to make ourselves understood or, more likely, still smiling, answering us in our own tongue. We owe many thanks to them, members of a small nation who took on themselves our entertainment and laid open all their resources to make the Eighth Assembly of the U.G.G.I. a very notable one.

RECORDS OF SNOW COVER ON SCOTTISH MOUNTAINS

BY GORDON MANLEY, M.A., M.SC.

It is often possible to find in old journals much neglected material of which use can be made in present-day discussions. Recently while looking through the *Journal of the Scottish Meteorological Society* for 1878, I found a short paper* by Alexander Cruickshank of Aberdeen summarising 21 years of daily observations, taken at noon, giving the average frequency with which six hills and mountains visible to the south-west from Aberdeen were " entirely or more than half " covered with snow. The summits were about 5, 10, 20, 25, 35 and 45 miles distant, namely Clochendichter (545 ft.), Cairnmonearn (1,245 ft.), Kerloch (1,747 ft.), Mount Battock (2,555 ft.), Mount Keen (3,077 ft.) and Lochnagar (3,786 ft.). In each case the north-easterly slopes were visible. It is evident that, although the more distant summits are often seen from Aberdeen, assumptions must have been made regarding the persistence of the snow cover during intervals when they were not visible. Cruickshank's earlier paper in the same Journal records that over 21 years Lochnagar was visible from Aberdeen on an average of one day in four.

From the viewpoint, apparently within two miles south of the centre of the city, it appears that reasonable estimates for the mean height of the lower part of the various summits visible are respectively 400, 800, 1,200, 1,600, 2,200 and 2,900 ft. If Cruickshank described the summit in question as " entirely or more than half covered " it would be fair to assume that half or more of the ground was likely to be covered at whatever lower level on the hill might be regarded as " generally visible " from Aberdeen. He also states that half or more of the ground " about Aberdeen " was covered on an average of 25 days per annum between 1857 and 1877.

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*CRUICKSHANK, A.; Observations at and near Aberdeen of certain meteorological phenomena. *J. Scot. met. Soc., Edinburgh,* New Series, 5, 1878, p. 197.

The extremely severe winter of 1878–9, with for example 63 days of snow cover even in the outskirts of Sunderland, is not included in Cruickshank's period ; and for 1857–77 it appears that the mean annual temperature differed little from that of the period 1912–46 for which the mean annual frequency of snow cover at the morning observation was 14·4 at Aberdeen Observatory (80 ft.). For 1925–46 however the mean frequency at Craibstone (300 ft.) was 31 days, although the latter is but 5 miles from the seashore. It is evident that the frequency of snow cover round Aberdeen was much the same as at present, allowing for Cruickshank's viewpoint and the extremely rapid increase as one moves inland to higher ground. Three years' observations at Dyce (240 ft.) give the impression that the mean frequency there would be of the order of 24 days over the past 30 years ; Cruickshank's figure is therefore acceptable for the area " round the city ".

For the various higher levels estimated above, his figures are given in Table I, together with modern data in Table II since the inception of snow-cover observations in the *Monthly Weather Report* in 1912.

TABLE I—AVERAGE ANNUAL NUMBER OF DAYS OF SNOW COVER, 1857-77
(Aberdeenshire)

" Ground more than half covered at noon "		Range of variation
" Round Aberdeen "	25	7–47
At 400 ft.	32	15–55
At 800 ft.	46	21–72
At 1,200 ft.	63	35–99
At 1,600 ft.	92	51–154
At 2,200 ft.	116	71–177
At 2,900 ft.	153	104–200

TABLE II—SOME PRESENT-DAY VALUES

	Height	Period	Average	Range	Authority
	ft.	yr.	days	days	
Craibstone	300	22	31	8–80	*Monthly Weather Report*
Logie Coldstone	608	15	43†	—	
Balmoral	930	35	60	27–116	
Braemar	1,114	34	67	—	
Drumochter (A. 9)	1,500	—	75	—	Estimated, see *Quart. J. R. met. Soc., London,* **65**, 1939, p. 2
Cairnwell Road (A. 93)	2,200	—	110–120		
Cairngorm Summits	3,000	—	165	—	
Ben Nevis	4,406	—*	230	—	

*Based on period 1883–1904. †Approximate.

The agreement of the above figures with present-day values and estimates is evidently good ; it is agreeable to find how well they confirm certain estimates made in my 1939 paper[*]. In view of drifting it is always rather doubtful just how much of an exposed hill summit will remain covered by snow by comparison with neighbouring slopes and valleys. Cruickshank was in each case looking at the north-east slopes, rather than the actual summits, and from a considerable distance ; but his original and apparently neglected observations deserve bringing to light as an effort to deal with an interesting question of British climatology. Especially they will prove interesting in the light of the efforts made by the Association for Study of Snow and Ice, now the British Glaciological Society, to observe and record the duration of mountain snow cover since 1938[†]. For example in the mild year 1938 snow cover at

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[*] MANLEY, G.; On the occurrence of snow-cover in Great Britain. *Quart. J. R. met. Soc., London,* **65**, 1939, p. 2.

[†] MANLEY, G.; Observations of snow-cover on British mountains. *Quart. J. R. met. Soc*, *London,* **67**, 1941, p. 1.

3,000 ft. was observed on 130 days, a figure comparable with that for the mild year 1868 on Lochnagar.

Cruickshank also noted the days on which snow and sleet fell. Unfortunately he makes separate totals for snow and sleet and it cannot be determined on how many days both forms of precipitation were recorded and distinguished. Direct comparisons cannot therefore be made with modern records, unless some Aberdeen enthusiast finds the original diaries, and we have already a fair picture of the frequency of snow from the Culloden and Edinburgh observations for the period in question. Snow cover was, however, so rarely tabulated by any method comparable with the modern standard that Cruickshank's pioneer effort is noteworthy, especially as we have so little data from the higher summits of the Scottish Highlands.

For the coastal lowland and the highlands respectively it is notable that the winters with the lowest frequency of snow cover are by no means the same ; and the effect of cold springs such as those of 1860 and 1877 in prolonging the upland snow cover is very evident. Near the coast, 1872, 1868 and 1873 were particularly snow-free whereas on the uplands 1857 and 1858 were relatively the least snowy seasons. In the other direction, 1860 and 1867 were snowy near the coast, whereas 1877, 1859 and 1860 were characterised by prolonged cover on the summits. It may be added that for the noticeably snowy year 1947, as many as 59 days were recorded at Aberdeen, 80 at Craibstone and 108 at Braemar. 1947 was therefore very remarkable at low levels near the coast, but was not quite so snowy as 1917 or 1919 at Braemar ; and presumably, therefore, on the mountains above.

The general trend of these observations from Aberdeen can also be checked with the aid of a long record of the frequency of snow cover kept by T. W. Backhouse, on the outskirts of Sunderland, from 1857 to 1915. These in turn can be continued with the aid of the modern data from several north-eastern stations beginning in 1912. While Backhouse's method of observation is again not precisely equivalent to that now adopted his monthly and annual figures can be regarded as broadly applicable for 200 ft. above sea level. It appears that the frequency of snow cover near the north-east coast in 1878–79 (63 days) was closely comparable with that of 1946–47 (about 60 days). The winter of 1916–17 gave about 50 days. No other winter appears to have given more than 40 days although a number gave between 35 and 40, the average being about 14. It is to be hoped that, scattered about the country, other records of the frequency and persistence of snow cover may come to light, from which further estimates of the long-period range of variability of this element may be derived.

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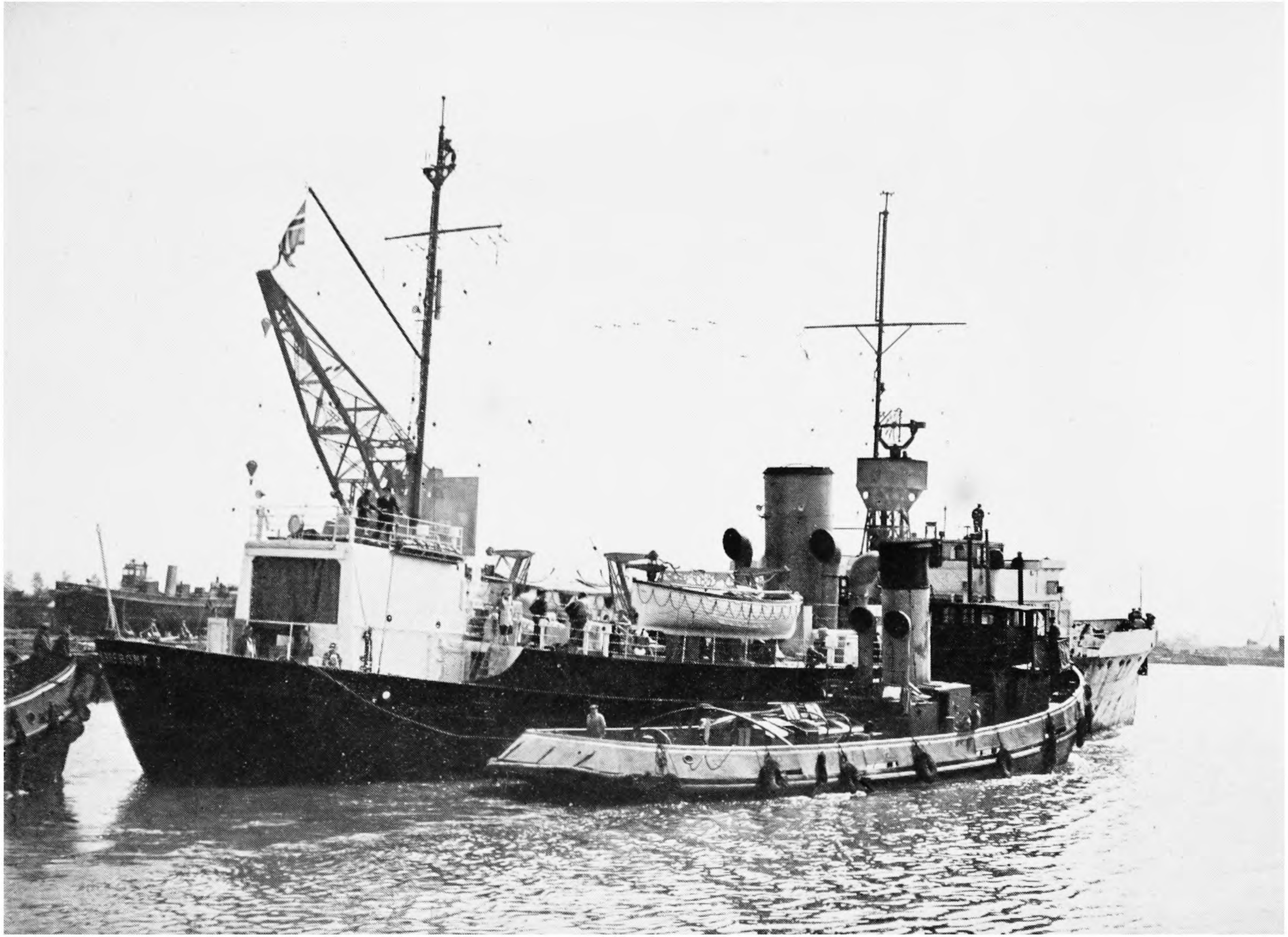

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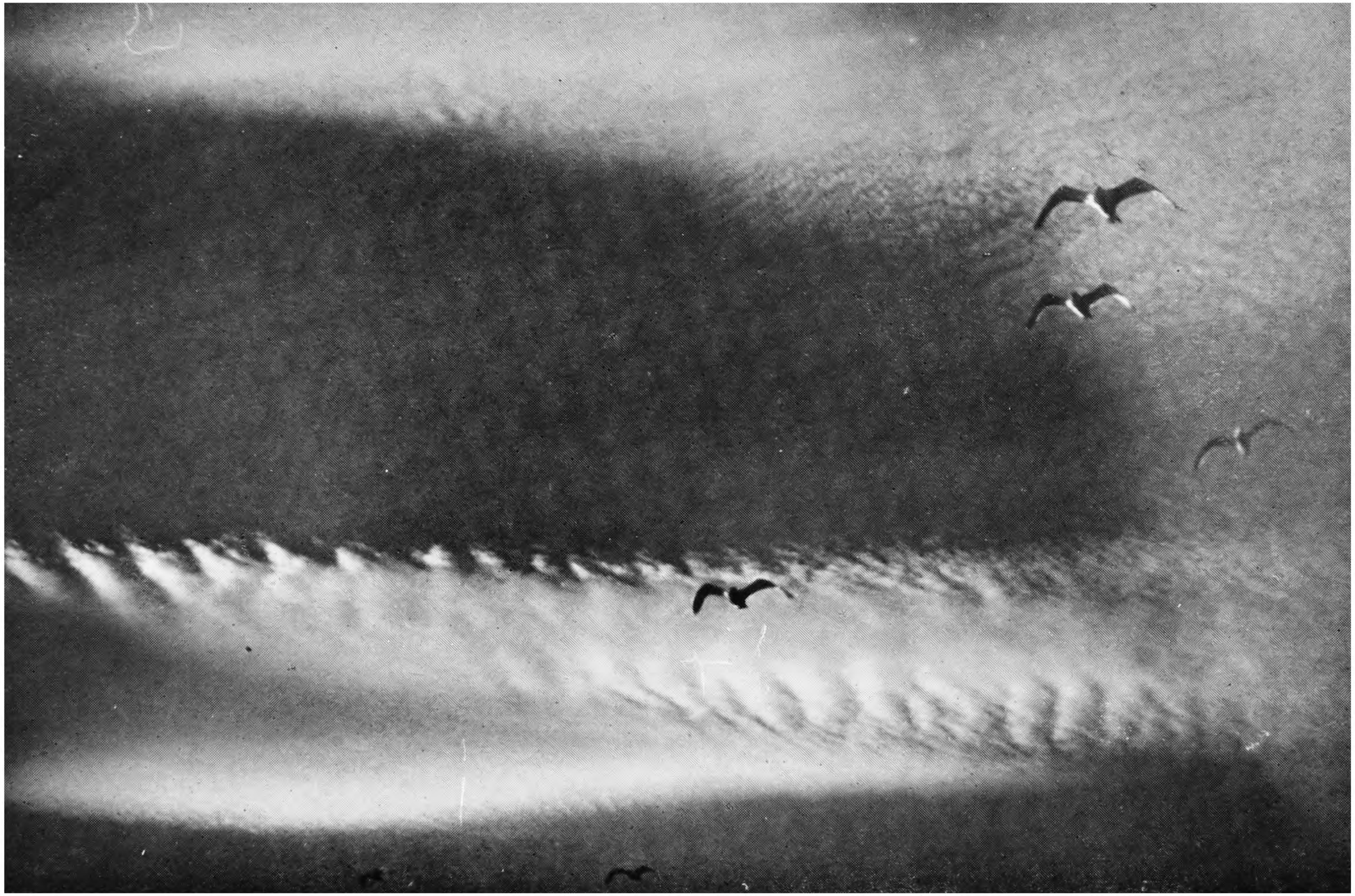
O.W.S. *Polarfront I* LEAVING CHATHAM NAVAL DOCKS, MAY 22, 1948

The *Polarfront I* and *Polarfront II* are manned by Norwegians and operate at station M (66°N. 2°E.), which is the joint responsibility of Great Britain, Norway and Sweden.



Reproduced by courtesy of O. M. Ashford

ALTOCUMULUS AND CIRROCUMULUS LENTICULARIS

Photograph taken from the *Weather Recorder* off Rathlin Island about 1600 G.M.T., July 25, 1948

USE IN AGRICULTURAL METEOROLOGY OF TABLES FOR GREAT-CIRCLE SAILING

BY N. CARRUTHERS, B.SC.

An important problem in agricultural meteorology is that of determining angles of incidence of the sun's rays upon a sloping hillside, at a place S (say), at different times of the day. P. J. H. Unna, in a letter to *Nature** shows that the computations involved are greatly simplified by the use of Towson's tables.† The present note is a more detailed account of the method outlined by Unna in *Nature*.

Suppose that the hillside in question, at S, approximates to a plane surface inclined to the horizontal at an angle β and that the vertical plane through the line of greatest slope ‡ makes an angle α with the north-to-south direction. Unna terms α the " aspect " of the slope.

Fig. 1 represents the great circle of the earth in the plane of the line of greatest slope at S, C being the centre of the earth. The slope at S is in the direction SD, and T is the point of contact of the (nearer) tangent plane parallel to SD. From the cyclic quadrilateral, KTCS, it is easily seen that the great-circle arc, TS, subtends an angle β at C. Since the mean circumference of the earth is very nearly 21,600 nautical miles, the length of TS in nautical miles may be expressed as 60β, where β is measured in degrees.

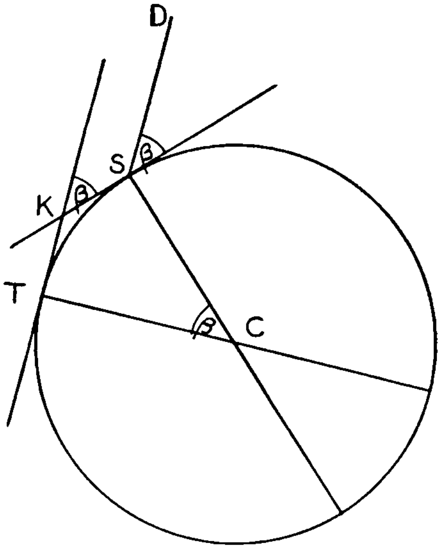


FIG. 1

The sun may be presumed to be at an infinite distance, and so the angle of incidence (but not the intensity) of the sun's rays on the slope SD at S will be equal to that on a horizontal surface (TK) at T, at exactly the same time. Thus, if the position of T is known, the usual tables giving elevation of the sun at T can be used for the sloping hillside at S, the only correction necessary being that of expressing the time at T in terms of local (or standard) time at S when T differs from S in longitude.

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*UNNA, P. J. H.; Angle of incidence of sun's rays. *Nature, London*, **160**, 1947, p. 713.

†TOWSON, J. T. and ATHERTON, J. W.; Tables to facilitate the practice of great circle sailing. London, 6th edn., 1916.

‡This plane is shown as DFG in Fig. 2, p. 276.

The problem has therefore been resolved into that of finding a point T distant 60β miles from S along the great-circle course which makes an angle α with the north-south line at S. The method of deriving the latitude and longitude of T from Towson's tables is outlined below and a simple example is given in detail. T lies to the north or south of S according to whether the slope at S faces north or south.

Let ϕ_S and ϕ_T be the latitudes of S and T and let λ be the difference in longitude between them. In the simple case in which the aspect of the slope at S is due north or south, T is in the same longitude as S and differs in latitude by exactly β. For a slope towards the equator, when $\alpha = 0$,

$$\lambda = 0, \quad \phi_T = \phi_S - \beta.$$

If $\beta > \phi_S$, ϕ_T becomes negative and T lies in latitude $\beta - \phi_S$ in the opposite hemisphere to S. For a poleward slope, when $\alpha = 0$,

$$\lambda = 0, \quad \phi_T = \phi_S + \beta.$$

This rule is quite simple so long as β does not exceed $90^\circ - \phi_S$. If $\beta > 90^\circ - \phi_S$, the rule still holds but T is found to lie on the opposite side of the pole to S and its position is given more conveniently by :

$$\lambda = 180^\circ, \quad \phi_T = 180^\circ - (\phi_S + \beta).$$

When α is not zero, T can be found by Towson's tables as described below.

Method of computation.—Let ϕ_V be the latitude of the vertex, V, of the great circle through S and T. The differences in longitude between S and V and T and V may be denoted by λ_S and λ_T so that λ is either the sum or difference of λ_S and λ_T.

Towson's tables are arranged in 89 major columns each of which refers to a great circle. The latter is specified by the latitude of its vertex ; that is, by its point of maximum latitude. Each major column is divided into three minor columns giving latitude, direction of course, and distance (along the great circle) from the vertex. The first step, in finding ϕ_T and λ is to pick out the major column, ϕ_V in which latitude ϕ_S corresponds most closely to " course " α. It is evident that ϕ_V will always be greater than ϕ_S except when $\alpha = 90^\circ$. When $\alpha = 90^\circ$, S coincides with V because a great circle runs east and west only at its points (one in each hemisphere) of maximum latitude. Interpolation between major columns to get a more exact value of ϕ_V is unnecessary, for even a difference of a whole degree in ϕ_V makes no appreciable difference to the values obtained subsequently for ϕ_T and λ (see Table I).

In the major column ϕ_V the line is found in which " Lat." and " Course " are as nearly as possible equal to ϕ_S and α respectively. D_S, a rough approximation to the distance of S from V, is extracted from the minor column labelled " Dist." and λ_S from the side column " Longitude from the vertex." It is as well to give λ_S to the nearest half degree, D_S being taken as the mean between two successive values of " Distance " where necessary. Finer linear interpolation is needed only when λ_S approaches 90° where the difference in latitude between successive lines of the table exceeds 2°.

The next step is to find D_T, the approximate distance of T from V. If the slope at S faces equatorwards, 60β is added to D_S to give D_T ; if the slope faces polewards, 60β is subtracted.

In the same major column ϕ_V as before, the line is found in which the " distance " is D_T' such that, as nearly as possible,

$$\begin{aligned} &\text{when } D_T \text{ is negative, } D_T' = -D_T \\ &\text{when } D_T \text{ is positive and less than 5,400, } D_T' = D_T \\ \text{and } &\text{when } D_T \text{ exceeds 5,400, } D_T' = 10{,}800 - D_T \end{aligned}$$

Where necessary D_T' may be taken as the mean of the " distances " in two consecutive lines, and finer linear interpolation may be required between the last few lines of the table. The entry under " Lat." in the line determined is ϕ_T, which should be rounded off to the nearest whole degree ; and the entry in the side column, " Longitude from vertex," is λ_T which is required to the nearest half degree.

The difference in longitude, λ, between S and T is found from the sum or difference of λ_S and λ_T. When D_T is positive, S and T lie on the same side of the vertex and $\lambda = \lambda_S \sim \lambda_T$; when D_T is negative they lie on opposite sides and $\lambda = \lambda_S + \lambda_T$. It is not difficult to decide whether λ should be added to or subtracted from the longitude at S to give the longitude of T : for an easterly facing slope, T lies to the east of S ; for a westerly, to the west of S.

The latitude of T is given directly by ϕ_T. If D_T exceeds 5,400, and this is possible only when ϕ_S is less than β, T is on the opposite side of the equator to S and ϕ_T refers to the opposite hemisphere. As a matter of interest it may be remarked that a slope with a southerly aspect in the northern hemisphere does not necessarily get more sun than a horizontal surface : if $\beta > 2\phi_S$, for values of α near 0°, the latitude of T will be greater than that of S.

TABLE I—EXTRACT FROM TOWSON'S TABLES

LATITUDE OF VERTEX									Longitude from vertex
75°			76°			77°			
Lat.	Course	Dist.	Lat.	Course	Dist.	Lat.	Course	Dist.	
° ′	° ′	′	° ′	° ′	′	° ′	° ′	′	°
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
50 33	24 3	2216	52 31	23 30	2105	54 37	22 57	1989	71
49 5	23 17	2312	51 3	22 43	2200	53 10	22 9	2082	72
47 30	22 32	2415	49 29	21 58	2301	51 38	21 21	2181	73
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
40 1	19 46	2896	42 23	19 1	2780	44 22	18 18	2655	77
37 48	19 9	3036	40 13	18 22	2922	42 12	17 37	2797	78
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..

Summary of computation method

(1) Column ϕ_V is that in which ϕ_S under " Lat." corresponds to α under " course " ($\phi_V \geqslant \phi_S$).

(2) D_S is the " Distance," in column ϕ_V, corresponding to ϕ_S, and λ_S is the corresponding " longitude from the vertex ".

(3) For southerly aspects (northern hemisphere), $D_T = D_S + 60\beta$; for northerly aspects (northern hemisphere), $D_T = D_S - 60\beta$.

(4) ϕ_T (nearest whole degree) is the latitude, in column ϕ_V, corresponding to "Dist." D_T if $|D_T| < 5{,}400$, or corresponding to distance $10{,}800 - D_T$ if $D_T > 5{,}400$; and λ_T is the corresponding "Longitude from the vertex".

(5) λ is the sum or difference of λ_S and λ_T according to whether D_T is negative or positive. For easterly (westerly) aspects, T lies to the east (west) of S; and, if $\lambda = H$ hours, sunrise and sunset are H hours earlier (later) at T than at S.

Example.—It is required to find the position of T corresponding to a slope of 1 in 5, facing south-south-east in latitude 52°. This slope (at the place S) is shown diagrammatically in Fig. 2, DG being the line of greatest slope.

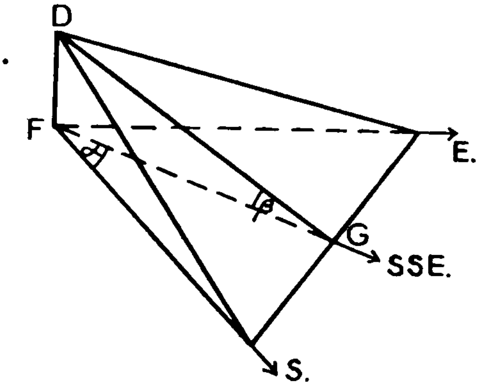

FIG. 2

Here, $\alpha = 22\frac{1}{2}°$ (the angle between south and south-south-east), $\phi_S = 52°$N. and $\tan \beta = \text{DF/FG} = 1/5 = 0{\cdot}2$, i.e. $\beta = 11°19' = 679'$.

We know that ϕ_V is greater than 52°: opening the tables at random, I find that, for $\phi_V = 80°$ (heading of column), 62°44′ under "Lat." corresponds to 22°16′ under "course" and 51°59′ under "Lat." corresponds to 16°23′ under "course". We require $\phi_S = 52°$ to correspond to $\alpha = 22\frac{1}{2}°$. Moving back through the table, we find the combinations shown in Table I.

Our best choice appears to be $\phi_V = 76°$, and the line showing latitude 51°3′. Corresponding to this latitude, we find $D_S = 2{,}200$ and $\lambda_S = 72°$.

The aspect is southerly, and so
$$\begin{aligned} D_T &= D_S + \beta \\ &= 2{,}200 + 679 \\ &= 2{,}879 \end{aligned}$$
where β, D_S, D_T are all expressed in minutes of arc or nautical miles.

Running down the same column, $\phi_V = 76°$, possible values for D_T are 2,780, 2,852 (halfway) or 2,922, and the nearest to D_T is 2,852. The other figures taken halfway between the lines give $\phi_T = 41°$ and $\lambda_T = 77\frac{1}{2}°$, and so, D_T being positive,
$$\begin{aligned} \lambda &= \lambda_T - \lambda_S \\ &= 77\tfrac{1}{2}° - 72° \\ &= 5\tfrac{1}{2}°. \end{aligned}$$

The aspect of the slope at S is easterly and therefore T is a place in latitude 41°N., $5\frac{1}{2}°$ longitude further east than S. The apparent noon on the slope at S is about 22 minutes before midday.

The stages of computation of ϕ_T and λ for a slope of 40° in latitude 46°N. are given in Table II. These values of ϕ_T and H (longitude expressed in hours) agree quite well with those given by P. J. H. Unna (shown in parenthesis) and appear sufficiently accurate for agricultural purposes.

TABLE II—COMPUTATION OF THE CO-ORDINATES OF T FOR A HILL SLOPE OF INCLINATION 40° IN LATITUDE 46°N.

Symbols with suffix letters S, T and V refer to values at S, T and V; λ and H are difference in longitude between S and T in degrees and hours respectively.

$\phi_S = 46°,\ \beta = 40°$, i.e. $60\beta = 2{,}400$

α	0	10	20	30	40	50	60	70	80	90
ϕ_V	90	83	76	70	63	58	53	49	47	46
λ_S	—	83	75	67½	58½	49	39	27	14	0
D_S	—	2627*	2525	2373	2192	1882	1559	1109	579	0
	Southerly aspect									
D_T	—	5027	4925	4773	4592	4282	3959	3509	2979	2400
D_T'	—	5027†	4907	4773†	4618	4296	3960	3502	2985	2407
ϕ_T	6	6†	8	10†	12	15½	19	23	28	33
ϕ_T (Unna)	(6)	(7)	(8)	(10)	(12·5)	(15·5)	(19)	(23)	(28)	(33·5)
λ_T	—	89½	88	86½	84	80	75	68	60	50½
λ	0	6½	13	19	25½	31	36	41	46	50½
H	0	0·4	0·9	1·3	1·7	2·1	2·4	2·7	3·1	3·4
H (Unna)	(0)	(0·4)	(0·85)	(1·25)	(1·65)	(2·05)	(2·45)	(2·75)	(3·0)	(3·35)
	Northerly aspect									
D_T	—	+227	+125	−27	−208	−518	−841	−1291	−1821	−2400
D_T'	—	227	125	21	205	518	840	1291	1840	2407
ϕ_T	86	82	76	70	63	57	51	45	39	33
ϕ_T (Unna)	(86)	(81·5)	(76)	(70)	(63·5)	(57)	(51)	(45)	(39)	(33·5)
λ_T	—	28½	8½	1	7½	16	22½	31	41	50½
λ	0	54½	66½	68½	66	65	61½	58	55	50½
H	0	3·6	4·4	4·6	4·4	4·3	4·1	3·9	3·7	3·4
H (Unna)	(0)	(3·65)	(4·35)	(4·55)	(4·5)	(4·3)	(4·1)	(3·85)	(3·65)	(3·35)

*D_S interpolated linearly with respect to ϕ_S

†ϕ_T interpolated linearly with respect to D_T

EFFECT OF HOUSE-BLOCKS OF TOWNS ON THE FALL OF TEMPERATURE AT NIGHT

By D. BERÉNYI, Ph.D.

(Professor at the Meteorological Institute of the University of Debrecen, Hungary)

In the March 1948 number of the *Meteorological Magazine*, Mr. W. A. L. Marshall* deals with the effect of the building, containing the Meteorological Office, on the maximum and minimum temperatures read in a Stevenson screen on its roof by comparison with " open space " data from Kensington Palace Gardens.

I dealt with a similar subject by other methods and from a different point of view in an article† published in the Hungarian periodical *Időjárás* in 1930.

I compared 476 minimum temperatures read at two points in the town of Debrecen. One of these points was on the fourth floor (height 20 m.) of a building in the centre of the town and the other in an open space 3 Km. from the centre of the town. The observations were made every night from August 1928 to December 1929.

My aim was the investigation of the effect of the heat radiation of the houses on the fall of temperature at night and on the factors influencing this effect.

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*MARSHALL, W. A. L.; London temperatures. *Met. Mag., London,* 77, 1948, p. 54.

†BERÉNYI, D.; A városi háztömbök hatása az ejjeli lehűlésekre. *Időjárás, Budapest,* **34**, 1930, p. 46.

The method used was to correlate the difference in the minimum temperatures at the two places with the mean cloudiness and wind velocity using averages of the 9 p.m. and 7 a.m. local mean time observations.

The results of the comparison are given in Table I.

TABLE I—AVERAGE DIFFERENCE OF NIGHT MINIMUM TEMPERATURES

Mean cloudiness	Wind speed (m./sec.) 0·0–1·0	1·1–2·4	2·5–5·0	>5·0
tenths	°C.	°C.	°C.	°C.
0·0– 2·0 ..	3·7 (56)	2·1 (40)	1·5 (19)	0·2 (13)
2·1– 4·0 ..	2·9 (14)	2·2 (18)	1·4 (13)	0·7 (7)
4·1– 6·0 ..	2·1 (26)	2·3 (33)	0·9 (18)	0·8 (14)
6·1– 8·0 ..	1·8 (13)	1·1 (13)	0·5 (26)	0·2 (10)
8·1–10·0 ..	1·0 (44)	0·8 (39)	0·8 (39)	0·1 (16)

Number of observations shown in brackets.

The observations definitely showed that as cloudiness and wind speed increased the average differences in the two minima decreased, the increase in wind speed having a greater effect than increase in cloudiness.

Table II shows the effect of cloudiness and wind speed separately.

TABLE II

Mean cloudiness (tenths)	0·0–2·0	2·1–4·0	4·1–6·0	6·1–8·0	8·1–10·0
Difference in minimum temperature (°C.) ..	2·6	2·0	1·7	0·8	0·8
No. of observations ..	128	52	91	67	138

Mean wind speed (m./sec.)	0·0–1·0	1·1–2·4	2·5–5·0	>5·0
Difference in minimum temperature (°C.) ..	2·4	1·7	0·9	0·4
No. of observations ..	153	148	115	60

With clear sky and light wind the average difference was 3·7° to 6·7°C. but on one occasion the difference was as high as 6·7°C. and on 23 occasions exceeded 5°C.

According to Mr. Marshall's table (p. 57) the difference between the Victory House roof and Kensington Palace Gardens reached 10°F. (5·5°C.) which agrees quite well with the differences found in Debrecen.

[Night minimum temperature differences of more than 9°F. between the ground and 20 m. were much more frequent at Debrecen on the nights examined by Prof. Berényi than between the ground and about 40 m. in London over the year August 1946–July 1947. The extreme differences at the two places were about the same. This is probably because Prof. Berényi's observations were made over a 16-month period including one whole winter and part of a second.

An adequate comparison cannot be made without further details of the "fourth-floor" thermometer exposure.—W. A. L. MARSHALL]

METEOROLOGICAL OFFICE DISCUSSION

The first discussion of the 1948–9 series was held in the Imperial College on Monday September 27, 1948. Dr. Frith introduced the paper "Production of rain by chain reaction in cumulus clouds at temperatures above freezing" by Irving Langmuir.*

In any cloud if there are some drops larger than average, these drops will fall. Under suitable conditions they will grow by coalescence, until they reach the limiting (breaking-up) size. The rate at which these drops grow depends upon their size and the nature of the cloud through which they fall. But it depends also upon the "efficiency of catch". Langmuir, using formulæ calculated with the aid of a differential analyser, develops tables, largely empirical, showing the efficiency of catch of a drop of radius S falling through a cloud of particles of radius r. (He assumes throughout that there is no "bounce-off" of droplets.) From these tables he calculates the conditions under which the drop will grow to the limiting size.

Next Langmuir studies the effect of a vertical current. Consider a falling drop which breaks up into smaller drops at a level z_0. If the vertical current is greater than the falling velocity of the resulting fragments, these will ascend. The fragments, being still large compared with the size of the cloud particles, will grow as they ascend. If they, in turn, split up before they have descended to the level z_0, then a chain reaction will have commenced and the number of large drops in the cloud will increase. The accumulation of large drops will eventually cause a down-draught, which will be compensated by increased turbulence in other parts of the cloud. Moreover the loss of quantities of water will decrease the density of the cloud and may, consequently, result in increased vertical development.

This theory is applied to an experiment in the Hawaiian Islands. A cumulus cloud with base at 2,500 ft. and top at 8,700 ft. (freezing level at 15,000 ft.) was seeded with crushed dry ice. Within 9 min. rain began and spread over a considerable area; two hours later the cloud had developed to over 15,000 ft. Langmuir deduced that the vertical currents must have been at least 600 cm./sec.

Dr. Frith then gave an account of "Operation Cirrus", Langmuir's work on the artificial nucleation of clouds.†

After discussing laboratory experiments on the production of ice crystals in a cloud of supercooled water droplets, Langmuir describes a series of experiments in which crushed dry ice was dropped into natural supercooled clouds. He states that the results of such experiments were always spectacular: the portion of the cloud "seeded" changing quickly into an ice-crystal cloud and slowly subsiding, sometimes leaving a completely cloud-free "lane", the effect spreading sideways at about 3 m.p.h.

In addition to describing these experiments, Langmuir discussed the use of silver iodide as a *nucleating* agent, and he spoke also of the possibility of (*a*) making rain, (*b*) clearing paths for aircraft through icing conditions.

On these last two points Dr. Frith emphasised that (*a*) none of the experiments of Operation Cirrus, as described by Langmuir, had produced any significant amount of rain, and (*b*) there was no report of paths being cleared through such clouds as altostratus or cumulonimbus (in which the most serious icing is found).

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*Published by the General Electric Research Laboratory, Schenectady, N.Y., 1948.

†LANGMUIR, I. and others; First quarterly progress report, Meteorological research, 1 March—1 June 1947. Washington, D.C., 1947.

In the discussion which followed, Sir Nelson Johnson referred to the fact that the particles in any cloud are never of uniform size. There are always a few larger ones. One might therefore query the necessity for the artificial introduction of large particles to set off a chain reaction. With regard to the second paper Sir Nelson spoke of a discussion on the artificial production of rain at the meeting of the U.G.G.I. at Oslo recently. Dr. Reichelderfer, Head of the United States Weather Bureau, had deplored the sensational claims which had been made with regard to rain-making and had pointed out that, in every case in which Langmuir's team had made rain, it had been raining naturally within 30 miles.

Mr. Absalom referred to the question of coalescence of drops and pointed out that laboratory workers, working it is true with drops of 1 or 2μ, had never observed coalescence.

Mr. Ludlam suggested that the initial large drop, required to set off a chain reaction naturally, could arise by normal condensation processes since the vapour pressure over a large drop is less than over a small drop; so that, in time, any drop which had initial advantage would grow at the expense of smaller drops.

Dr. Scrase remarked that Langmuir had not taken into account the effect of an electric field, or of electric charges on the drops.

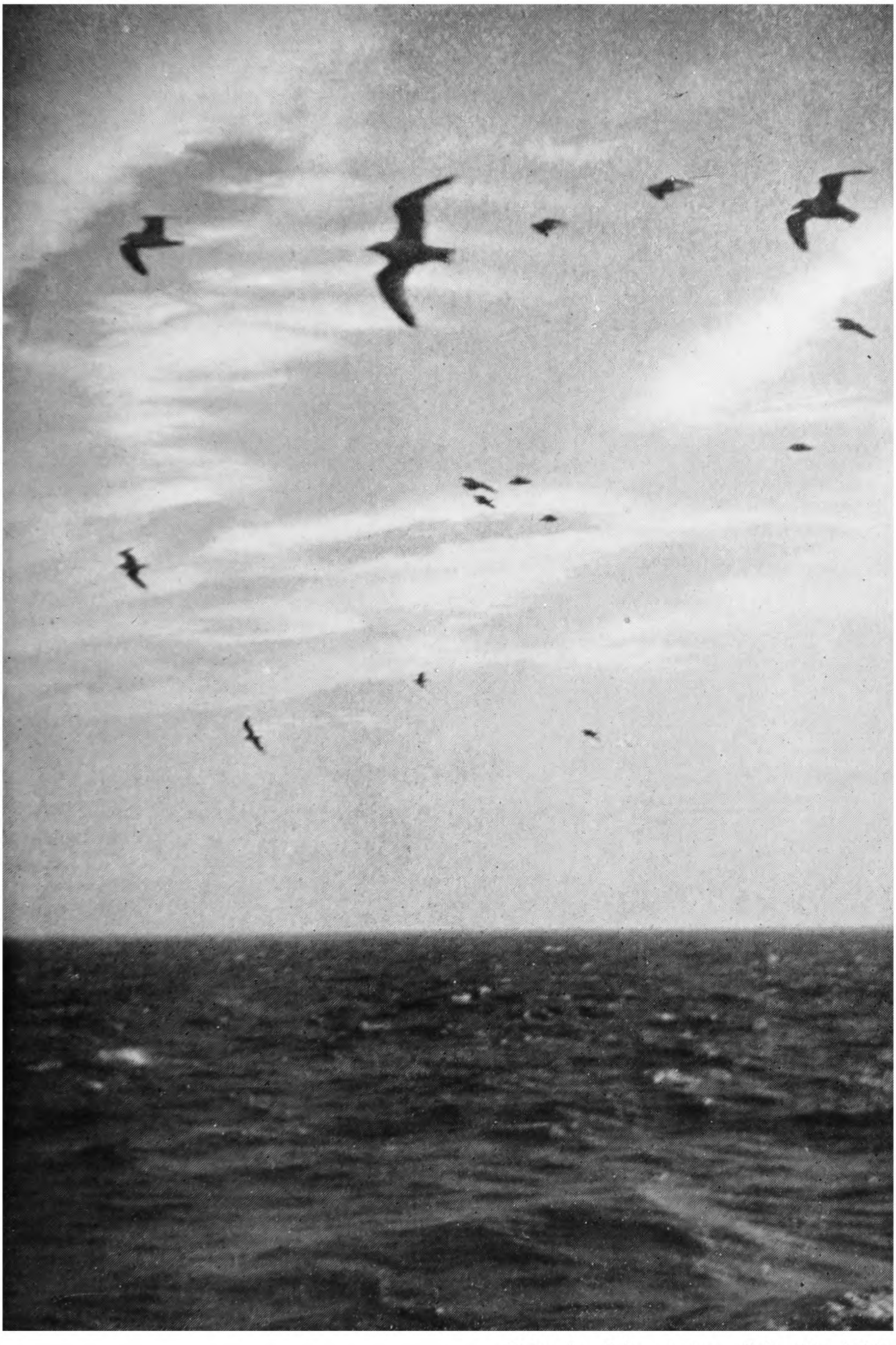
Prof. Sheppard emphasised the value of Langmuir's work, whilst agreeing that the economic value of rain-making might have been exaggerated. He tnought that although Langmuir's figures might in places be in error, there was no reason to suppose that the ideas might not be fundamentally sound.

Dr. Sutcliffe remarked that what most meteorologists would want to know was to what extent Langmuir's work influences current ideas. He suggested that there was nothing in the work inconsistent with the generally accepted idea that most raindrops originate as ice crystals. With regard to the second paper Dr. Sutcliffe suggested that most clouds, if made to precipitate completely out, would provide only insignificant amounts of rain.

In reply, Dr. Frith agreed with Dr. Sutcliffe's conclusions in so far as this country is concerned, but remarked that the chain-reaction process might be the rule rather than the exception in some tropical regions. Whilst it is true that the amount of water in most clouds is not sufficient to give a significant rainfall if precipitated out, there are three points to be borne in mind : (*a*) there is some merit merely in clearing cloud, (*b*) Langmuir referred to the possibility of a self-generating cloud resulting from a seeding process, and (*c*) in orographic cloud, seeding might result in copious and prolonged rainfall.

METEOROLOGICAL RESEARCH COMMITTEE

The 55th meeting of the Meteorological Research Committee, a joint meeting with the Aeronautical Research Council, was held on October 12. At this meeting the nature of the meteorological information required by the designers and operators of aircraft was reviewed and the extent to which existing information is inadequate was examined. The general conclusions were that statistical information about winds and temperatures at greater heights and over the whole globe is required, that further information about turbulence is needed in connexion with the stresses imposed on aircraft and that more quantitative



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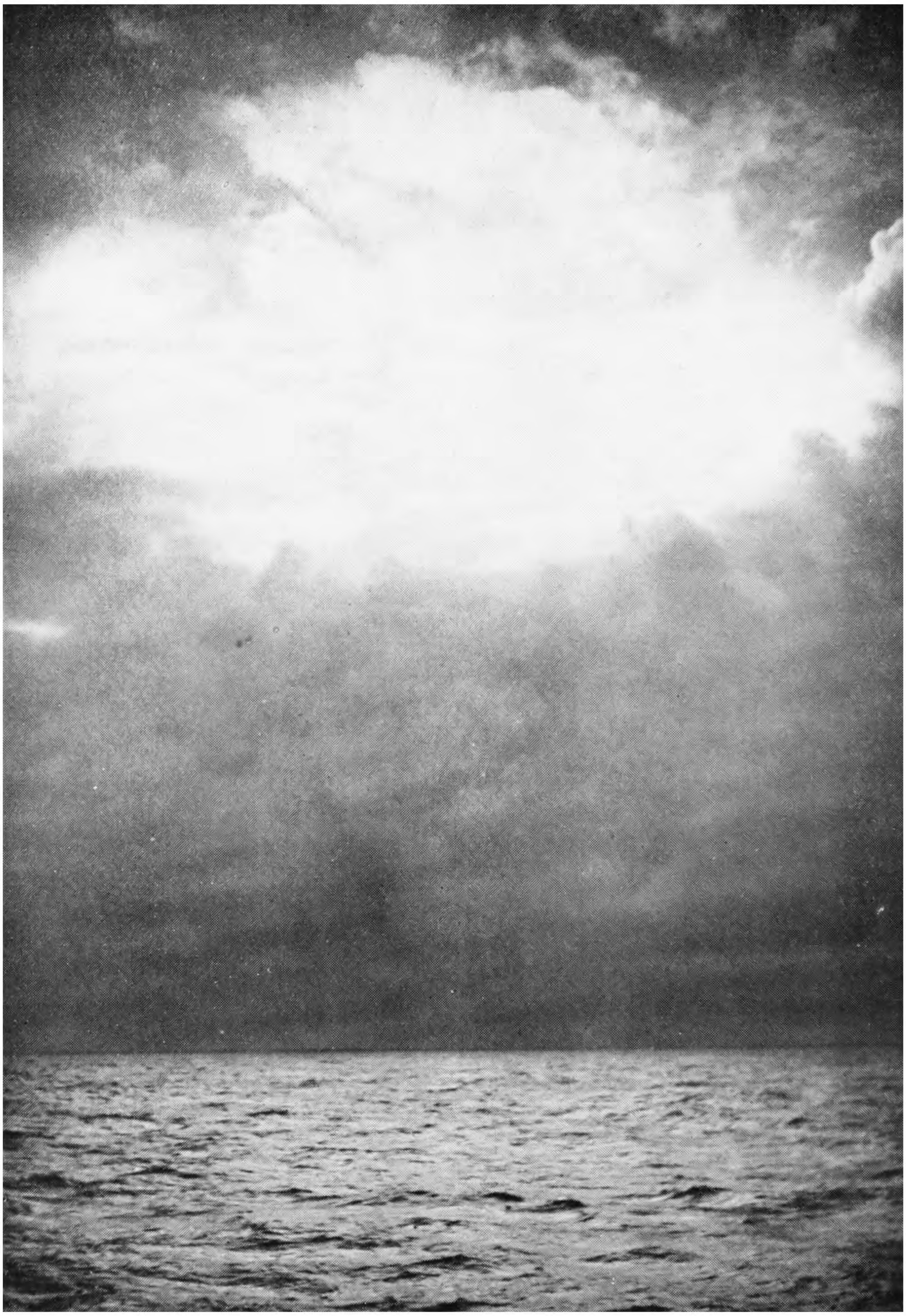
ALTOCUMULUS AND CIRROCUMULUS LENTICULARIS

Photograph taken from the *Weather Recorder* off Rathlin Island, about 1600 G.M.T., July 25, 1948



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IN THE REAR OF A COLD FRONT

Photograph taken at 2030 G.M.T. at station JIG, July 18, 1948 information is necessary about the concentration and form of liquid water in the atmosphere at sub-freezing temperatures in connexion with de-icing problems.

The 4th meeting of the Physical Sub-Committee was held on October 21. Papers considered included *Met. Res. Publ.* No. 424, by Mr. F. Pasquill, which deals with temperature and humidity gradients in the lowest two metres of the atmosphere and discusses the evaluation of evaporation from a grass-covered surface. Two papers by Mr. J. K. Bannon (*Met. Res. Publ.* Nos. 436 and 437) were also discussed. These two papers deal with the occurrence of clear-air turbulence at high altitudes and suggest that a major factor in the occurrence of this phenomenon may be wind shear in the horizontal.

OFFICIAL PUBLICATIONS

The following publication has recently been issued :—

GEOPHYSICAL MEMOIRS

No. 81. *The aurora of January* 25 *to* 26, 1938 *and associated magnetic storm.* By F. E. Dixon, B.A.

The auroral display of January 25 to 26, 1938, was the most spectacular for many years, and the associated disturbance of the earth's magnetic field was of exceptional severity. This memoir, the publication of which was delayed by the war, summarises the available observations of both classes of phenomena and relates them to solar conditions.

Estimates of their positions show that the principal auroral arcs were about 90 Km. above the earth. One of these arcs extended from the Baltic to at least 200 Km. west of Ireland. The rays reached heights exceeding 500 Km.

Other features discussed are electric-current systems in the upper air over the British Isles at the time, and the question as to whether or not any sounds can be identified as due to the aurora.

Illustrations include reproductions of magnetograms and two attractive plates of the aurora, one depicting it as seen from the Mediterranean.

LETTERS TO THE EDITOR

Variation of temperature in a free-water surface

The article by Mr. Stormonth in the August number, on variations of temperature in a free-water surface, brings to the foreground a question of great interest and importance to all meteorologists—perhaps especially from the synoptic viewpoint. Although the measurements concerned were taken in idealised conditions—in perfectly still water—the gradients concerned are of such a magnitude that it makes one wonder what the readings would be in relatively calm water at sea.

Observations have shown that very considerable horizontal gradients do occur at sea, not only at margins (fronts) of widely differing currents (e.g. the Gulf Stream and Labrador current) but also in almost any part of the ocean. These gradients (casual, variable or constant though they be) may be due to upwelling of a body of cold water, to variations in density, to the confluence of varying currents at different depths, or to local heating by the sun. It is certain that these gradients are sometimes quite steep. Anyone who has bathed off the British coast will have experienced these temperature gradients close inshore.

A vertical gradient in the upper 10 m. of the sea is also of considerable interest to the meteorologist; the skin surface temperature, being that with which the air mass under consideration is in contact, is that in which he is primarily interested, but it is rarely that he is able to obtain that.

The methods employed at sea for obtaining the water temperatures are:—

(*a*) The bucket method, whereby a sample of water is obtained from a bucket lowered over the side, the thermometer being immersed in the water after the bucket has been hauled on deck. In this case, the water is probably obtained from a mean depth of about 1 ft. below the surface.

(*b*) The intake method, whereby the temperature of the water flowing to the condenser is measured. The intake itself may be anything from 10–30 ft. below the surface.

It seems probable, but not certain, that in rough weather so much mixing takes place, that there is practically no gradient in the upper part of the 10 m. layer, but even 20 ft. is a fair depth and it is doubtful if much disturbance takes place at this depth (except, say, with a force 7 wind).

In very calm weather, it seems that very little mixing will take place at sea, and in such conditions on a hot, sunny day, it seems that a very appreciable vertical gradient may exist. A ship moving through the water will, it seems certain, stir the water up to a considerable extent and observations taken from the ship, whether from the bucket or the intake, will presumably indicate a mean temperature of the " block " of water concerned. It seems that this will not be the temperature of the skin surface of the water, which is presumably what the meteorologist desires.

This problem was quite extensively discussed at the recent International Meteorological Organization meetings at Toronto, by both Commissions for Maritime Meteorology and for Instruments and Methods of Observation. It could not be decided whether the bucket method (assuming an insulated bucket is used and errors are thereby reduced to a minimum) or the intake method was preferable. Quite apart from the gradient problem, both methods have distinctive practical limitations and liability to error. It was, however, decided that the problem needed investigating, and countries operating ocean weather ships were asked to co-operate.

The British ocean weather ships are fitted with thermographs in the intake at about 12-ft. depth, and comparisons with " bucket " readings are made. Arrangements are also being made to take sea-water observations from rubber dinghies away from the ship.

Attempts to investigate these problems were made, at the request of the Marine Branch of the Meteorological Office, aboard certain merchant ships in the North Atlantic during the war, and a large number of comparative readings between intake and bucket methods were made. The results were found to be extremely variable, however, and no exact conclusions could be reached, apart from the fact that the canvas bucket which was then in use was an unreliable apparatus.

C. E. N. FRANKCOM

October 2, 1948

Aurora

I should like to put on record some observations of the aurora made on the north-east coast of Ireland two miles north of Donaghadee at about 2300 G.M.T. on the nights of September 29–30 and October 3–4 and 4–5, 1948. On all three occasions there was a steady glow, yellowish in colour, and not unlike the glow to be seen when the sun is a few degrees below the horizon in cloudless weather. This glow had roughly the shape of a segment of a circle, with the highest point directly under the pole star. In that direction (i.e. approximately true north) there was open sea for more than 50 miles, and the only large town that might possibly have caused a glow in the sky was Belfast, which lay in a west-south-west direction well outside the area of the glow. On the first of the three occasions three faint rays could be seen, extending beyond the glow and roughly perpendicular to its upper " boundary " if such a word can be used for anything so vague.

E. V. NEWNHAM

October 11, 1948

NOTES AND NEWS

Sir Napier Shaw Memorial

The Royal Meteorological Society has recently decided to establish a Memorial Fund to endow a " Napier Shaw Award of the Meteorological Society ". It is hoped that the Fund will be sufficiently well supported to permit the foundation of a post-graduate scholarship tenable anywhere within the British Commonwealth.

The Council of the Royal Meteorological Society has circulated an appeal to its members, but it is thought that there may be many people who are not members of the Society who would like to associate themselves with this scheme. The pre-eminent position occupied by Sir Napier Shaw in laying the scientific foundations of meteorology, his long connexion with the Meteorological Office (1897–1919) and his world leadership as President of the International Meteorological Organization, are factors which should make this appeal of interest to a very wide field.

I am authorised by the President of the Royal Meteorological Society to say that it is not intended to restrict this scheme within the membership of the Society, and that contributions from other sources will be welcomed. They should be sent to the Executive Secretary of the Royal Meteorological Society at 49 Cromwell Road, London, S.W.7.

N. K. JOHNSON

The variability of means of a series of observations

It is well known that in a random series of observations of standard deviation σ, the standard deviation of the means of n successive values is given by $\sigma/\sqrt{n}$. If the series is not random, but has " persistence ", this simple rule no longer holds.

Let $x_1 \ldots x_p \ldots x_n$ be a series of observations with standard deviation σ, and a correlation r between successive values. Then, if σ_2 be the standard deviation of means of pairs of values,

$$\sigma_2{}^2 = \sum_{p=1}^{n-1} \tfrac{1}{4}(x_p{}^2 + x_{p+1}^2 + 2x_p x_{p+1})/(n-1)$$

$$\Sigma x_p x_{p+1}/(n-1) = r\sigma_1{}^2$$

and therefore $\sigma_2 = \sigma_1 \sqrt{\left(\frac{1+r}{2}\right)}$ .. (1)

In theory, if the correlation coefficient of successive terms is r, that between terms p and $p + n$ should be r^n. Then if σ_n be the standard deviation of means of n successive values

$$\sigma_n = \sigma_1 \sqrt{[n + 2\{(n-1)r + (n-2)r^2 + \ldots + r^{n-1}\}]/n} \quad .. \ (2)$$

To test this expression, daily pressure readings at Kew for October 1938 to March 1939 were expressed as differences from the average for the whole series, and then combined in means of successive sets of 2, 3, 4, 6, 8, 12, 16. The standard deviation of the individual observations was 10·67 mb. and the autocorrelation coefficient 0·667. The standard deviations of the various sets are shown by the crosses in Fig. 1, while the smooth curve shows the values calculated by expression (2). It is seen that the crosses lie entirely above the smooth curve, i.e. the standard deviations given by expression (2) are too small.

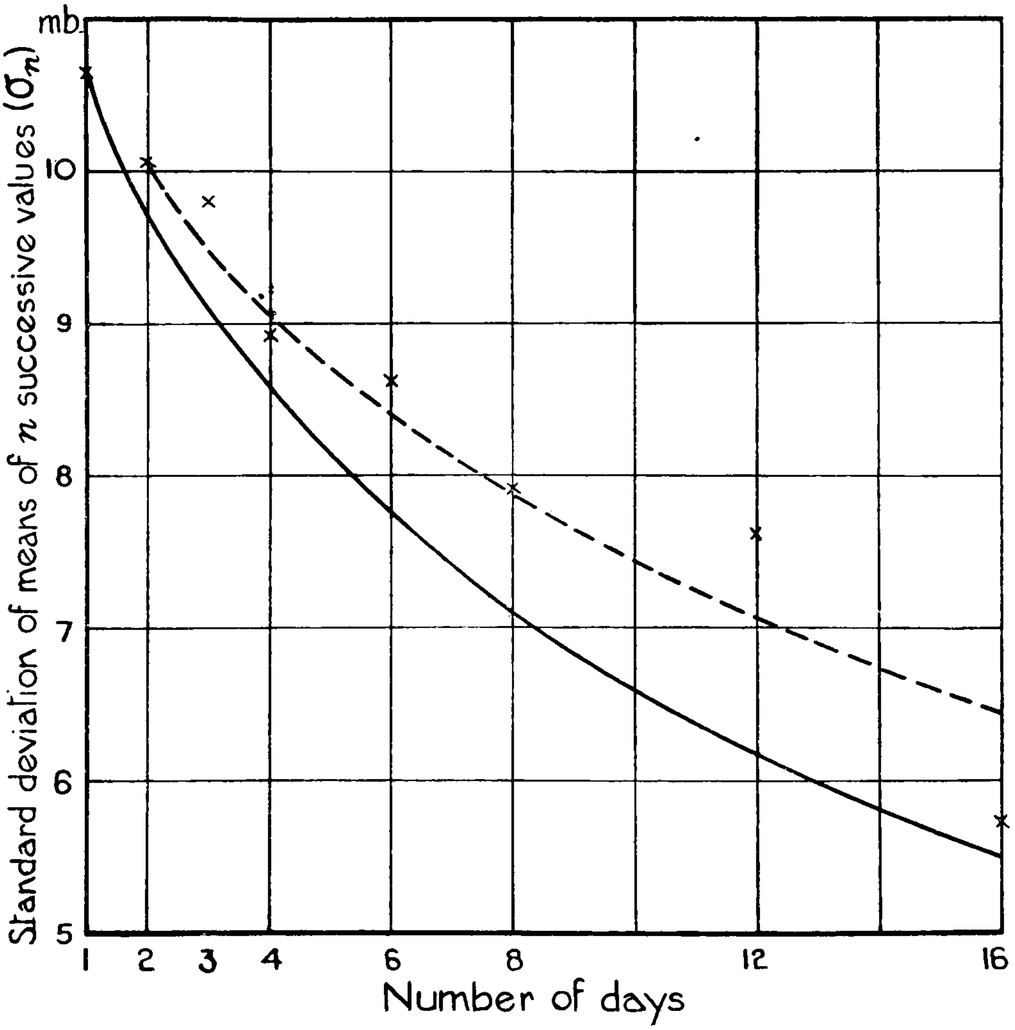

FIG. 1—CALCULATED AND OBSERVED STANDARD DEVIATIONS OF PRESSURE AT KEW, OCTOBER 1938 TO MARCH 1939

This is obviously because, in meteorological series, " persistence " is not constant but increases with time. If pressure is high on one day, there is a good chance that it will be high on the second day, but if pressure has been high on two successive days, the probability that it will be high on the third day is increased, and so on. Consequently a new series of standard deviations were calculated, beginning with that for the mean of two successive days, and using the autocorrelation coefficient r_2 between successive means of two days, which was 0·624. The result is shown by the broken line in Fig. 1, which is a reasonably good fit for the observations. With only 182 days, the numbers of successive means of 12 and 16 days are only 15 and 11 respectively, so that the observed standard deviations naturally show a good deal of scatter.

It may be remarked that for independent observations with standard deviation 10·67 mb., σ_{16} would be only 2·67 mb., so that the effect of day-to-day persistence is quite marked over half a month. With means over still longer periods, the effect of persistence gradually decreases.

C. E. P. BROOKS

WEATHER OF OCTOBER 1948

During the first three days of the month pressure was rather high over England while an anticyclone was moving away across northern France. A new anticyclone reached England from the west on the 5th, but soon moved away eastwards, and for about a week the British Isles lay between large depressions to the west and north-west, and anticyclones to the east or north-east. Between the 17th and 18th a secondary depression moved north-eastwards across England, and on the 22nd a large and very deep depression, moving at about 40 m.p.h. passed eastwards across the Faeroes, reaching Finland early on the 23rd. Another depression moved north-eastwards across the Hebrides on the evening of the 24th, but pressure became rather high after the 25th, at first as a result of a wedge connected with an anticyclone over the Azores and then owing to the development of a large anticyclone centred over Scandinavia, with pressure 1040 mb. near the centre from the 29th to the 31st.

Monthly mean pressure was above 1020 mb. in the states of Virginia, Ohio and Pennsylvania, in the Azores, and from central Europe across to the Black Sea, and was 1000 mb. in the south-west of Iceland. It was 5 to 10 mb. below the average for October in north-east Greenland, northern Scandinavia, Finland and north-west Russia, and generally slightly above the average in the U.S.A., in the Azores, in the British Isles, and from France to the western frontiers of Russia.

In the British Isles the weather was changeable; mild weather prevailed until the 25th, apart from a cool spell around the 4th to 6th but it was cold from the 26th onwards. The month was unusually wet in the west of Scotland but dry over most of England and Wales. Exceptionally severe gales occurred in the extreme north of Scotland on the 22nd and 25th.

During the opening days an anticyclone over southern England and northern France moved slowly east-south-east. Meanwhile secondary troughs of low pressure moved north-north-east along our north-west seaboard causing rain in the west and north, which was heavy in the west of Scotland on the 1st (3·60 in. at Ardgour, Argyllshire and 2·72 in. at Fort William). Subsequently an anticyclone moved slowly east across the British Isles and a spell of mainly fair weather prevailed apart from some rain in the south-west on the 6th. By the 8th a complex area of low pressure covered the North Atlantic and troughs of low pressure approached our western districts; strong winds and gale locally occurred on the north-west coasts and considerable rain fell in Scotland and Ireland, many stations in Scotland recording more than 2 in. of rain on the 9th. In England and Wales conditions continued fair. On the 11th a small secondary depression moved north-east from the south-west of Ireland; rain occurred fairly generally on the 11th and thunderstorms were widely recorded in the south-east on the 12th. A very unsettled period ensued with secondary depressions or troughs of low pressure moving east over the British Isles; rain fell daily in most areas. On the 17th a small but vigorous secondary depression moved rapidly north-east across England giving heavy rain, while the main depression south of Iceland moved east-south-east. In the rear of these disturbances westerly gales were recorded locally in the English Channel. On the 21st and 22nd a small, very vigorous, depression moved east across Iceland and associated troughs crossed the British Isles; widespread gales occurred in Scotland on the 22nd and they were very severe in the extreme north, Beaufort force 11 being reached for a time at Lerwick. Another intense disturbance moved east to the north of Scotland on the 24th and then turned north-east. Severe gales were recorded in the extreme north of Scotland, hurricane force being reached at Wick at 0600 on the 25th. Rain occurred at times in most districts.

In the rear of this disturbance a wedge of high pressure moved east over the British Isles and subsequently high pressure was established over southern Scandinavia. The last six days of the month were cold; among low minimum temperatures may be mentioned 17°F. at Dalwhinnie, 21°F. at Wick and 22°F. at South Farnborough on the 27th. On the 27th and 28th a depression off the west of Ireland moved south-east and was associated with heavy rain in the south-west and local gales on the south-west coasts (2·37 in. of rain at St. Austell on the 27th).

Broadly speaking, rainfall exceeded the average in Scotland except south of the Firth of Forth, around Balmoral and the Solway Firth; more than twice the average occurred in Argyllshire. In England and Wales more than the average occurred in Cornwall, in an area extending from north Wiltshire to Birmingham and locally in south Wales, west Essex and north Cambridgeshire. Less than 50 per cent. was received over much of north-east England, locally on the coast of East Anglia and in part of south-east England.

The general character of the weather is shown by the following provisional values:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	75	21	+0·5	75	−4	93	29
Scotland	67	11	0·0	130	0	108	28
Northern Ireland..	70	28	+1·3	100	−1	104	28

Erratum.—September table, p. 262, Highest temperature in Scotland, *for* 72°F. *read* 70°F.

RAINFALL OF OCTOBER, 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·96	75	*Glam.*	Cardiff, Penylan ..	5·61	118
Kent	Folkestone, Cherry Gdns.	1·20	30	*Pemb.*	St. Ann's Head ..	4·16	94
,,	Edenbridge, Falconhurst	1·89	53	*Card.*	Aberystwyth	4·78	115
Sussex	Compton, Compton Ho.	2·94	64	*Radnor*	Bir. W. W., Tyrmynydd	4·37	66
,,	Worthing, Beach Ho.Pk.	1·80	50	*Mont.*	Lake Vyrnwy	2·56	43
Hants	Ventnor, Roy. Nat. Hos.	2·20	56	*Mer.*	Blaenau Festiniog ..	9·51	93
,,	Bournemouth	1·95	46	*Carn.*	Llandudno	2·10	63
,,	Sherborne St. John ..	2·58	73	*Angl.*	Llanerchymedd ..	2·65	59
Herts.	Royston, Therfield Rec.	2·26	83	*I. Man.*	Douglas, Boro' Cem. ..	4·10	90
Bucks.	Slough, Upton	2·26	81	*Wigtown*	Port William, Monreith	5·17	131
Oxford	Oxford, Radcliffe ..	2·33	81	*Dumf.*	Dumfries, Crichton R.I.	3·44	87
N'hant.	Wellingboro', Swanspool	1·57	62	,,	Eskdalemuir Obsy. ..	5·97	111
Essex	Shoeburyness	1·04	44	*Roxb.*	Kelso, Floors	2·44	84
Suffolk	Campsea Ashe, High Ho.	1·71	66	*Peebles*	Stobo Castle	2·21	64
,,	Lowestoft Sec. School ..	1·20	43	*Berwick*	Marchmont House ..	3·14	82
,,	Bury St. Ed., Westley H.	1·37	51	*E. Loth.*	North Berwick Res. ..	2·72	92
Norfolk	Sandringham Ho. Gdns.	2·18	72	*Midl'n.*	Edinburgh, Blackf'd. H.	1·61	59
Wilts.	Bishops Cannings ..	4·41	133	*Lanark*	Hamilton W. W., T'nhill	3·46	106
Dorset	Creech Grange.. ..	2·42	48	*Ayr*	Colmonell, Knockdolian	5·86	132
,,	Beaminster, East St. ..	3·29	74	,,	Glen Afton, Ayr San ..	..	..
Devon	Teignmouth, Den Gdns.	2·49	64	*Bute*	Rothesay, Ardencraig	10·56	239
,,	Cullompton	3·02	73	*Argyll*	L. Sunart, Glenborrodale	9·22	140
,,	Barnstaple, N. Dev. Ath.	4·28	94	,,	Poltalloch	10·56	214
,,	Okehampton, Uplands	5·35	89	,,	Inverary Castle.. ..	17·24	245
Cornwall	Bude School House ..	5·24	129	,,	Islay, Eallabus ..	7·93	166
,,	Penzance, Morrab Gdns.	5·99	129	,,	Tiree	6·63	145
,,	St. Austell, Trevarna ..	7·93	150	*Kinross*	Loch Leven Sluice ..	3·63	106
,,	Scilly, Tresco Abbey ..	4·58	120	*Fife*	Leuchars Airfield ..	2·93	113
Glos.	Cirencester	3·49	105	*Perth*	Loch Dhu	11·93	167
Salop.	Church Stretton ..	2·17	59	,,	Crieff, Strathearn Hyd.	4·76	121
,,	Cheswardine Hall ..	1·93	62	,,	Pitlochny, Fincastle ..	3·91	120
Staffs.	Leek, Wall Grange P.S.	2·39	69	*Angus*	Montrose, Sunnyside ..	2·83	103
Worcs.	Malvern, Free Library	2·65	89	*Aberd.*	Balmoral Castle Gdns...	1·90	53
Warwick	Birmingham, Edgbaston	2·83	102	,,	Dyce, Craibstone ..	3·97	118
Leics.	Thornton Reservoir ..	2·60	93	,,	Fyvie Castle	4·05	106
Lincs.	Boston, Skirbeck ..	1·74	64	*Moray*	Gordon Castle	3·24	103
,,	Skegness, Marine Gdns.	1·82	66	*Nairn*	Nairn, Achareidh ..	2·33	102
Notts.	Mansfield, Carr Bank ..	1·36	45	*Inv's*	Loch Ness, Foyers ..	4·47	133
Ches.	Bidston Observatory ..	1·69	52	,,	Glenquoich	14·86	149
Lancs.	Manchester, Whit. Park	2·41	73	,,	Fort William, Teviot ..	12·59	177
,,	Stonyhurst College ..	3·52	78	,,	Skye, Duntuilm ..	7·61	140
,,	Blackpool	3·58	96	*R. & C.*	Ullapool	5·14	109
Yorks.	Wakefield, Clarence Pk.	1·13	39	,,	Applecross Gardens ..	7·94	133
,,	Hull, Pearson Park ..	1·34	45	,,	Achnashellach	11·22	148
,,	Felixkirk, Mt. St. John	1·13	39	,,	Stornoway Airfield ..	4·85	99
,,	York Museum	1·31	49	*Suth.*	Lairg	4·66	125
,,	Scarborough	1·42	45	,,	Loch More, Achfary ..	9·09	117
,,	Middlesbrough.. ..	1·12	37	*Caith.*	Wick Airfield	4·33	146
,,	Baldersdale, Hury Res.	2·46	62	*Shet.*	Lerwick Observatory ..	5·79	146
Norl'd.	Newcastle, Leazes Pk. ..	1·58	51	*Ferm.*	Crom Castle	2·52	78
,,	Bellingham, High Green	2·31	59	*Armagh*	Armagh Observatory ..	2·26	83
,,	Lilburn Tower Gdns. ..	1·72	46	*Down*	Seaforde	2·65	74
Cumb.	Geltsdale	2·82	76	*Antrim*	Aldergrove Airfield ..	3·17	106
,,	Keswick, High Hill ..	4·94	88	,,	Ballymena, Harryville..	4·74	128
,,	Ravenglass, The Grove	4·04	94	*Lon.*	Garvagh, Moneydig ..	3·76	107
Mon.	Abergavenny Larchfield	3·79	90	,,	Londonderry, Creggan	4·56	124
Glam.	Ystalyfera, Wern House	6·14	89	*Tyrone*	Omagh, Edenfel ..	3·64	99

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, JUNE 1948

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1014·0	−2·8	78	46	65·8	52·0	58·9	−0·6	53·9	73	8·6	1·67	−0·48	16	5·4	33
Gibraltar	1017·5	+0·2	89	60	78·9	65·0	71·9	+1·4	66·8	76	3·1	0·14	—	2	11·6	80
Malta	1015·4	+0·2	86	60	79·5	65·2	72·3	−0·4	67·4	65	2·6	0·11	—	3	11·6	79
St. Helena	1019·1	+0·2	71	55	66·3	57·3	61·8	+1·5	57·3	91	8·9	2·22	−0·51	13	—	—
Freetown, Sierra Leone	1013·8	+3·5	88	67	83·7	73·1	78·4	−0·5	75·5	88	8·0	19·39	−0·65	28	4·1	33
Lagos, Nigeria ..	1014·2	+1·8	89	67	83·3	70·9	77·1	−2·4	75·7	87	9·1	9·45	—	20	3·0	24
Kaduna, Nigeria ..																
Chileka, Nyasaland ..	1022·7	+0·4	82	48	75·5	55·6	65·5	+0·5	59·1	63	2·9	0·01	−0·12	1	8·0	71
Lusaka, Rhodesia ..	1020·1	+0·9	79	45	74·9	49·9	62·4	+0·9	54·6	56	1·8	0·00	−0·05	0	9·8	—
Salisbury, Rhodesia ..	1023·2	+0·6	74	37	70·6	42·1	56·3	−0·9	50·2	56	1·0	0·00	−0·09	0	10·0	90
Cape Town ..	1021·4	+1·3	74	39	62·9	45·6	54·3	−1·4	46·8	76	5·9	2·86	−1·64	21	—	—
Germiston, South Africa	1024·4	−0·8	71	24	64·6	37·9	51·3	+1·0	39·1	60	0·0	0·00	−0·23	0	9·8	93
Mauritius																
Calcutta, Alipore Obsy.	998·4	−0·9	100	75	94·0	80·8	87·4	+2·3	81·5	84	6·6	12·76	+0·85	14	5·3	39
Bombay	1003·3	−0·7	95	75	90·4	80·6	85·5	+1·5	78·9	81	7·4	8·78	−11·09	11	5·4	41
Madras	1003·1	−0·7	110	77	102·1	83·4	92·7	+2·7	76·1	58	6·5	0·71	−1·26	8	7·4	57
Colombo, Ceylon ..	1009·3	+0·7	88	73	85·8	77·4	81·6	0·0	77·2	85	8·7	11·55	+4·23	25	6·1	49
Singapore	1008·8	−0·1	92	72	89·0	77·3	83·1	+1·6	78·2	79	6·7	6·62	−0·25	12	—	—
Hongkong	1004·2	−1·6	91	72	86·0	77·6	81·8	+0·4	77·9	85	—	17·16	+1·46	19	4·3	32
Sydney, N.S.W. ..	1022·4	+4·5	70	40	61·8	49·3	55·5	+0·8	49·8	79	5·4	7·48	+2·74	13	4·7	48
Melbourne	1023·2	+4·7	63	32	56·7	41·9	49·3	−1·1	44·6	82	6·9	1·33	−0·73	13	3·6	38
Adelaide	1024·0	+5·4	65	40	59·2	46·3	52·7	−0·9	48·1	76	7·7	1·82	−1·26	15	4·0	41
Perth, W. Australia ..	1019·4	+1·4	74	39	66·2	49·4	57·8	+1·0	53·1	68	5·0	7·13	+0·19	13	4·6	46
Coolgardie	1022·3	+3·4	73	35	63·3	43·3	53·3	+0·5	46·4	68	3·0	1·34	+0·08	8	—	—
Brisbane	1020·7	+2·4	77	42	68·7	51·3	60·0	−0·2	54·4	68	4·4	8·83	+6·04	10	6·1	58
Hobart, Tasmania ..	1019·7	+5·4	60	31	53·3	39·6	46·5	−0·5	41·4	77	6·6	1·34	−0·89	12	4·1	45
Wellington, N.Z. ..	1018·1	+3·2	61	35	52·0	42·3	47·1	−0·9	44·5	80	7·4	3·05	−1·72	15	3·1	34
Suva, Fiji	1013·4	−0·2	84	66	79·2	71·1	75·1	+0·4	71·3	81	7·9	4·47	−2·24	18	4·0	36
Apia, Samoa ..	1011·0	−0·3	89	69	86·8	73·7	80·3	+1·6	76·7	80	7·1	2·56	−2·42	14	8·2	73
Kingston, Jamaica ..	1013·9	+0·1	93	72	89·8	74·9	82·3	+1·0	75·9	73	4·2	9·69	+5·59	6	9·2	70
Grenada, W. Indies ..	—	—	88	73	86·5	76·8	81·7	+2·7	78·0	80	8·1	5·39	−2·86	21	—	—
Toronto	1013·0	−1·7	85	45	75·0	56·3	65·7	+1·9	55·4	69	5·5	4·06	+1·40	9	8·7	57
Winnipeg	1013·2	+1·4	90	35	73·2	50·0	61·6	−0·7	51·6	82	5·7	1·69	−1·42	14	9·3	57
St. John, N.B. ..	1012·3	−1·2	76	42	63·1	47·4	55·3	−1·2	50·8	83	6·6	4·72	+1·45	14	6·4	41
Victoria, B.C. ..	1016·9	+0·1	81	46	68·3	51·5	59·9	+2·9	52·3	92	5·1	1·76	+0·92	7	10·2	64